An investigation into the strategic application and acceleration of curriculum renewal in engineering education for sustainable development

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Abstract

At the beginning of the 21st Century, society faces a host of emerging urgent and inter-related issues such as climate change, biodiversity loss, ocean acidification, rising sea levels and access to diminishing resources such as oil, fresh water and arable land. The engineering profession is increasingly being called upon to play a key role in addressing these challenges, but requires significant capacity building within the next decade in order to do so. The need for such rapid curriculum renewal is particularly evident within undergraduate and postgraduate engineering education globally, where the process of fully integrating new knowledge and skills has been comparatively slow and *ad hoc*.

This dissertation addresses this need by exploring how curriculum renewal can be undertaken to meet rapidly changing expectations in urgent and challenging times, focusing on engineering education for sustainable development. The research uses a qualitative narrative approach which manifests itself in three main sources of data: literature from authors describing experiences and evolving theories; personal narrative of the researcher's previous project experiences; and peer review from experts in the field regarding the findings. Historical and ethnographic research methods are used, primarily comprising document analysis and archival research.

A significant gap in curriculum literature is highlighted, where few time-bound curriculum renewal processes are explicitly discussed, despite clear evidence of frustration about the need for rapid change within the field, and a substantial time lag evident in existing processes, particularly within the context of education for sustainable development. Six elements that support rapid curriculum renewal were distilled from the literature, personal experiences, and extensive peer review. These comprise: awareness raising and developing a common understanding; graduate attribute mapping; curriculum auditing; course development and renewal; bridging and outreach; and campus integration.

It is concluded that rapid curriculum renewal is possible through systematically applying these elements, however they are not in themselves accelerating mechanisms. Therefore timeframes need to be set by one or more catalysts, which may include accreditation, regulation and policy, and employer demand. Strong institutional leadership and support is critical in ensuring that the timeframes are addressed and that momentum is maintained. Strategic planning is also important to ensure adequate budget and resourcing, with clear stages that can be reviewed and reported against. These findings have immediate and significant implications for engineering education providers globally, in addition to having potential application in other similarly structured professional disciplines.

Statement of Originality

This work has not previously been submitted for a degree or diploma in any university. To the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is also made in the thesis itself.

Cheryl Desha
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Prelude

In the presentation of this dissertation, I make the following declarations of positions that have influenced me – as a researcher and research instrument – and subsequently my approach to developing and investigating the research question. At the end of this dissertation (see Postscript) I also reflect on how my positions and values have been affected by the research and its outcomes. It is essential to disclose such positions to ensure transparent, confirmable, and a reliable reference, particularly as I am the researcher and the research instrument, interacting with projects and colleagues. Such disclosure needs to satisfy other researchers that I am clear about how my values and interactions have shaped and influenced my research, and have themselves been changed through the process of research.

After graduating from Griffith University in 1999 as an environmental engineer, I worked for an engineering consultancy in Brisbane for four years, as part of an emerging sustainability team. Growing frustrated with the lack of awareness of emerging sustainable design methods and technologies amongst colleagues and clients in the built environment industry, in November 2003 I joined The Natural Edge Project (TNEP), a non-profit sustainability think-tank hosted by Engineers Australia, as the team's Education Coordinator. My primary goal was to help the team create educational materials that could assist engineers learn about such innovations, which I believed would help to fill a significant gap in undergraduate and postgraduate curriculum. In July 2004 in formal collaboration with TNEP I joined Griffith University School as an Associate Lecturer, gaining access to trialling new content and processes with engineering students and staff.

In a staff role, I began to see opportunities to formalise my largely intuitive understanding (grounded in undergraduate experiences) of how to engage in engineering education for sustainable development. In particular I had developed a strongly held view that engineering departments needed to fast-track curriculum renewal throughout the programs offered, to meet rapidly changing expectations of the role of engineers in society across government, industry and the community. This includes for example expectations that engineers will play a major part in solving issues such as reducing greenhouse gas emissions and adapting to climate change. In August 2005 I began my doctorate in a part time capacity in this area, continuing with related applied research projects and teaching responsibilities. In January 2007, TNEP transferred to Griffith University's Centre for Environmental Systems Research (2007-2008) and then the Urban Research Program (2009-2010). Throughout this period my role remained largely the same, except for Semester 1 2009 where I was provided with a teaching-free period to write.

My experiences in trying to undertake rapid curriculum renewal as both a lecturer and a researcher have been primary inputs in developing and exploring the research question. Additional primary inputs include literature across three fields: sustainable development; curriculum theory and engineering education. Moreover these personal experiences have directed the qualitative research approach which includes personal reflections through narrative inquiry as a significant component of the methodology (presented in Chapter 4). Through lecturing I interacted with undergraduate students from civil, environmental, micro-electronic engineering and software engineering, and postgraduate students from a variety of disciplines spanning engineering, education, law, business and information technology. Those interactions helped me to explore and witness the theory and practice of curriculum development as experienced by students.

Through TNEP research I was involved in a number of projects that helped me to test and evaluate various emerging aspects of rapid curriculum renewal. I have had access to projects with Australian and international universities, government agencies and corporate entities, and had many opportunities to explore mechanisms to accelerate curriculum renewal in engineering education for sustainable development with mentors in the field. This has helped me to iteratively refine the research question, the body of literature to be reviewed and emergent theoretical model. In particular, invited participation in five conferences and workshops (Barcelona 2007; Seoul 2008, Austria 2009; and Tokyo 2009, 2010) and one study visit to Hamburg (2006) helped me to continually seek feedback on my research findings from a wide variety of academics in engineering and science in a formal process of peer review (presented in Chapter 5), reducing the potential for my values and conviction to compromise the credibility of the research outcomes.

In summary, my values and positions can be seen in this research in a number of ways, where I am clearly implicated as both the researcher and also the research instrument: I have undertaken the literature review process; I have been involved as a project officer in a number of projects with colleagues which relate to the processes of curriculum renewal being researched, and I have subsequently examined these experiences. I have also coordinated, recorded and interpreted the peer review process. Moreover, the research is focused on investigating a strongly held viewpoint of mine, which is almost a mantra that accompanies me in the dissertation. I believe that working on rapid curriculum renewal within engineering curriculum is an important point of departure from existing research into timely capacity building for sustainable development, and is also an important contribution to the broader pedagogical question of how curriculum renewal may be accelerated in urgent and challenging times. It is with this declaration that I present this dissertation.

1. INTRODUCTION: NAMING THE PROBLEM

In this chapter the problem of focus in this dissertation is introduced, namely the need for rapid curriculum renewal in urgent and challenging times, with regard to engineering education and sustainable development. The chapter begins with a contextual overview of the problem, including a consideration of the changing role of the professions this century and the need for 'education for sustainable development' (ESD). The key role of the engineering profession in meeting sustainable development challenges is then overviewed, including the need for 'engineering education for sustainable development' (EESD), the state of progress towards EESD, and an observed 'time lag dilemma' requiring urgent attention. It also includes an overview of drivers that are promoting and limiting EESD. This context is used to shape the research problem and to define the approach of the study, including defining major terms which are used in the dissertation.

1.1 The need for curriculum renewal in higher education

By the early 20th Century the world had most of the scientific understanding, enabling technologies and methodologies needed to start to underpin a number of significant development feats. For example, advances in mobility led to trains, cars and planes moving people at a pace and over distances scarcely imaginable when the century began.[1] Air transport connected the world and continued to expand into the 21st Century as one of the fastest rising transport modes - with an 80 percent increase in kilometres flown between 1990 and 2003.[2] As a result of agricultural innovation and the use of pesticides and inorganic fertilisers, the world grain harvest quadrupled during the 20th Century, and with continued advances in chemistry, global chemical production is projected to increase by 85 percent by 2020.[3] Humans now have unprecedented access to raw materials and processed goods from around the world, with shipping alone rising from 4 billion tons in 1990 to 7.1 billion tons total goods loaded in 2005.[4]

With these considerable developments over the last century, the effectiveness of education for professions (i.e. through the higher education sector) would appear to be self-evident. Yet for all its successes, other signals now clearly suggest that the approach to higher education requires a significant update. As highlighted in a United Nations Environment Program report on working in a low-carbon world,

> *… companies in the fledgling green economy are struggling to find workers with the skills needed to perform the work that needs to be done. Indeed, there are signs that shortages of skilled labor could put the brakes on green expansion…There is thus a need to put appropriate education and training arrangements in place.*[5]

In addition to the atmospheric, land and water pollution associated with development, global pressures of burgeoning population growth and consumption are overwhelming current efforts to reduce environmental pressures. For example, the world's population is now growing at nearly 1 billion per decade,[6] increasing from 3.5 billion in 1970, to 7 billion in 2010.[7] In 1990 only 13 percent of the global population lived in cities, while in 2007 more than half did.[8] More than 60 percent of the global population lives within 100 kilometres of the coastline[9] and nearly all of the population growth hereon is forecast to happen in developing countries.[10]

Hence the future levels of stress on the global environment are likely to increase if current trends are used for forecasting, which is particularly challenging as scientists are already observing significant signs of degradation and failure in environmental systems. According to World Bank estimates, each year the economic losses China suffers from environmental pollution are equal to 5 to 10 percent of its GDP.[11] The Intergovernmental Panel on Climate Change (IPCC) *Fourth Assessment Report*[12] effectively ended debate concerning key aspects of the science of climate change, providing an 'unequivocal' link between climate change and current human activities, in particular: the burning of fossil fuels; deforestation and land clearing; the use of synthetic greenhouse gases; and decomposition of wastes from landfill. The UK *Stern Review* concluded that within our lifetime there is between a 77 to 99 percent chance (depending on the climate model used) of the global average temperature rising by more than 2 degrees Celsius,[13] with a likely greenhouse gas concentration in the atmosphere of 550 parts per million (ppm) or more by around 2100.

Together with the 2006 *Stern Review*[14] and release of the movie, *An Inconvenient Truth*,[15] the IPCC documents contributed to a historic 'tipping point' in public acknowledgement of these very real issues.[16] In particular, society world-wide has become much more aware of complex environmental systems and the need for strategic global action to stabilise these systems. For example, Stern highlighted strategic opportunities for stabilising greenhouse gas concentrations in the atmosphere, including both short term actions to stop increasing the emission of pollution such as greenhouse gases (i.e. 'peaking'), followed by sustained reduction in levels of pollution over the longer term (i.e. 'tailing').[17] As illustrated in Figure 1-1 for greenhouse gases, there are a number of peaking and tailing options to stabilising concentrations (referred to as carbon dioxide equivalent, or CO_2e) in the atmosphere; in this example at 550 parts per million (ppm). These are discussed in the following paragraph.

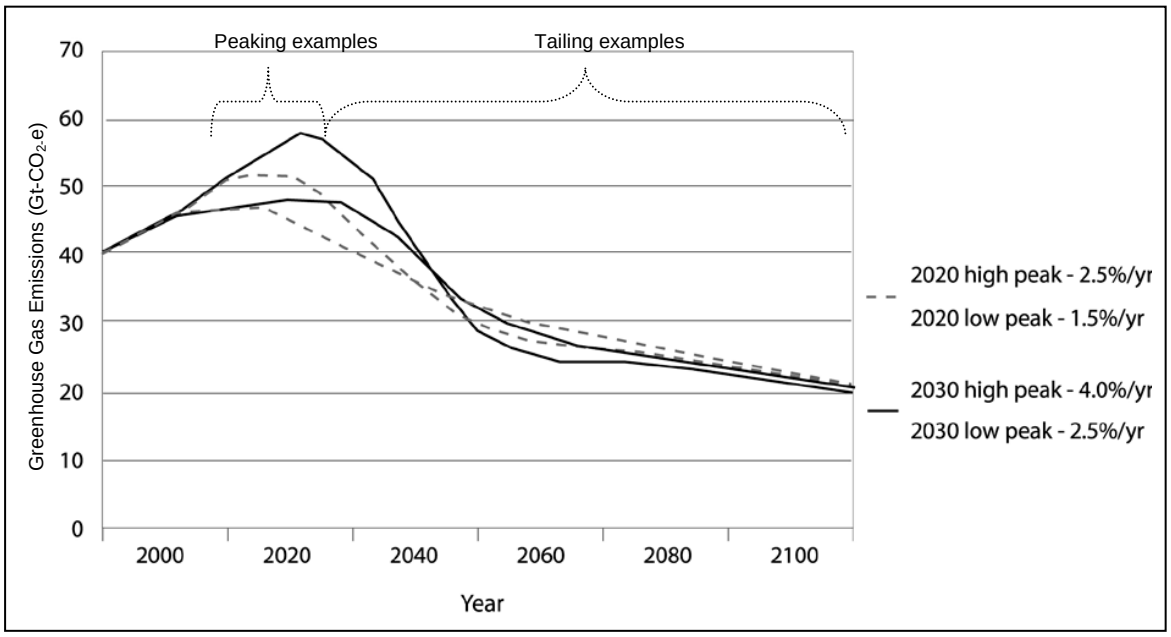

Figure 1-1. Illustrative emissions pathways to stabilise greenhouse gas emissions at 550ppm CO_2e, related to global GDP cost implications

Source: Adapted from Stern[18]

In addition to making a decision about the end goal for the system (for example achieving an atmospheric concentration of 550 ppm CO_2e), each option to achieve this – or each 'trajectory' – has its own economic and environmental implications. Essentially, achieving earlier and lower peaks can result in reduced longer term tailing requirements for the trajectory to reach the end stabilisation goal, but requires more upfront commitment. For example, achieving a 'low peak' of emissions at just over 50 billion tonnes (Giga-tonnes) per year in 2020 (i.e. 50 Gt-CO_2e) requires rapid short term reduction but then permits a level of sustained reduction costing around 1.5 percent of global GDP per year. In contrast, achieving a 'high peak' of emissions of nearly 60 Gt-CO_2e by 2030 results in more costly reductions, of around 4.0 percent of GDP per year.

In the publication *Cents and Sustainability*, authors Smith *et al*[19] refer to such measures for reducing environmental impacts while maintaining or improving economic performance as 'decoupling economic growth from environmental pressure'. Ideally, negative environmental impacts would be completely – or 'absolutely' – decoupled from economic performance, eventually being eliminated. Furthermore, positive environmental impacts (for example reforestation, aquifer recharge etc) would be 'recoupled' to economic performance so that as development proceeds, environmental systems are restored. This perspective is shared by leaders in the sustainable development field such as Brundtland, MacNeill, Pachauri, Sachs and Ruffing in their forewords to the publication.

However, despite this growth in awareness about the variety of strategic options available to address environmental system imbalances, subsequent action cannot be assumed. There are a number of well documented examples in recent history where societal 'development' has involved significant risk denial - of poverty in the 1950s; of causes of human immunodeficiency virus (HIV) transmission in the 1960s; of smoking being harmful in the 1970s; and of negative impacts to the planet's biosphere from the scale of industrial pollution from the 1980s through to the beginning of the 21st Century. Jared Diamond's historical consideration of civilisations past in *Collapse*,[20] clearly shows that humanity takes time to acknowledge, accept and then deal with issues that have significant ramifications on daily life, particularly those issues that seem to strike at the core of our values and sense of self. In *An Inconvenient Truth*, Gore cautions that society has typically reacted with either denial or despair when faced with the threat of ecosystem collapse, neither of which has resulted in action. Gore proposes that if stakeholders could be enabled to undertake the required actions in an appropriate timeframe, then the outcome might be a global community of prosperous nations that enjoy a quality of life within the Earth's carrying capacity, where sustainable development is the norm.

The definition of sustainable development referred to in *An Inconvenient Truth* and the aforementioned reports, was provided in a 1987 seminal report by the World Commission on the Environment and Development, commonly known as the 'Brundtland Report'. Here, sustainable development is defined in detail, with the most popular truncation as follows:

> *'… development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*[21]

Two decades later, this definition incorporates a multitude of emerging issues at the start of the 21st Century, including climate change and associated greenhouse gas emissions, declining ecosystems, species decline, diminishing oil supplies, increasing waste and pollution levels, and rapid development trends, especially in developing countries.[22]

David Orr, one of the world's leading environmental proponents, has argued for many years that the planetary crisis we face is actually a crisis of education.[23] Within the context of rapidly changing professional needs, educators are facing the significant challenge of providing knowledge and skills in a range of relatively new and emerging areas across industry, government and society, in both developed and developing countries. This was acknowledged more than two decades ago in the *Brundtland Report*, which advocated all types of education to reach out to as wide a group of individuals as possible, given that environmental issues and knowledge systems can *'now change*

radically in the space of a lifetime'.[24] As Griffith University Vice Chancellor Ian O'Connor stated at the Green Cross International 2006 Earth Dialogues forum in Brisbane, Australia (chaired by President Mikhail Gorbachev),

> *'Higher education is beginning to recognise the need to reflect the reality that humanity is affecting the environment in ways which are historically unprecedented and which are potentially devastating for both natural ecosystems and ourselves. Like the wider community, higher education understands that urgent actions are needed to address these fundamental problems and reverse the trends. Stabilisation of human population, adoption of environmentally sound industrial and agricultural technologies, reforestation, and ecological restoration are crucial elements in creating an equitable and sustainable future for all humankind in harmony with nature… The urgent challenge for higher education now is to include ecological literacy as a core competency for all graduates, whether they are in law, engineering or business'.*[25]

Such dialogue reflects an emerging consensus by higher education leaders such as O'Connor, that the ideal 'global community of prosperous nations' that Gore refers to needs an engaged higher education community that actively incorporates sustainability related emerging knowledge and skills into the education system, through sustainability education.

The United Nations has adopted the term 'Education for Sustainable Development' (ESD) to explain this need, which is defined as education that encourages *'changes in behaviour that will create a more sustainable future in terms of environmental integrity, economic viability, and a just society for present and future generations'*.[26] To-date, higher education may be seen as playing a role in 'education *about* sustainable development' rather than 'education *for* sustainable development'. The former may be regarded as an awareness lesson or theoretical discussion, whereas the latter is the use of education as a tool to achieve sustainability.[27] Education about sustainable development might acknowledge climate change as an issue and provide learning opportunities about the context and/or science of this phenomenon, while Education for sustainable development (ESD, also known as 'Education for Sustainability', or 'EfS') is about increasing the capacity of individuals, groups or organisations to contribute to sustainable development, through content and skills acquisition.

In essence, ESD is important for developing professional capacity to respond to the sustainable development challenges. Researchers Tilbury and Wortman have distilled the following skills from ESD literature, which they conclude should be learned and applied according to the cultural contexts of different groups and stakeholders:[28]

- *Envisioning* - being able to imagine a better future.
- *Critical thinking and reflection* - learning to question our current pattern of living and to recognise the assumptions underlying our knowledge, perspective and opinions.
- *Systemic thinking* - acknowledging complexities and looking for links and synergies when trying to find solutions to problems.
- *Building partnerships* - promoting dialogue and negotiation, working together.
- *Participation in decision-making* - empowering people.

Within this context, it is clear that ESD has three major dimensions, affecting all forms of education from early childhood through to vocational and higher education, and professional development:

- Firstly, it provides an overarching theme to education, grounding all learning in existing and emerging challenges, and needs of 21st Century society. This requires updating content taught, including for example the context described in the beginning of this chapter, spanning local to global contexts.
- Secondly it is about changing the educational approach from reductionist thinking, towards a whole system approach to addressing problems. This includes for example collaborative decision-making, interdisciplinary visioning and innovation, and sustainability concepts such as 'whole system design'[29], transformational change towards 'Factor 5'[30] or higher improvements in resource productivity, and 'net positive development'[31]. This may require quite a dramatic change in the way education is provided, including embedding new theory, knowledge, and examples into the curriculum (i.e. from the learning outcomes through to assessment requirements – this is discussed further in Chapter 3), and encouraging approaches such as problem or project based learning.
- Thirdly, it is about applying this change in mindset, through explicit teaching of emerging knowledge and skills that are relevant to each professional discipline in society. This spans disciplines such as engineering, planning, design, architecture, law, business, education, and trade specialisations including plumbers, electricians, carpenters, builders and labourers. The knowledge and skills taught may range from phasing in examples of emerging sustainable technologies, through to embedding emerging knowledge throughout programs, and phasing out education that caters to outdated needs that are counter-productive in achieving sustainable development.

Considering the transition of current societal practices to sustainable development, Smith *et al*[32] propose that the process can be considered in the form of the schematic shown in Figure 1-2, of levels of commitment to reducing environmental pressures. This

includes those organisations who are complying with industry requirements, those who are leading, and those who are demonstrating best practice education in their industry.

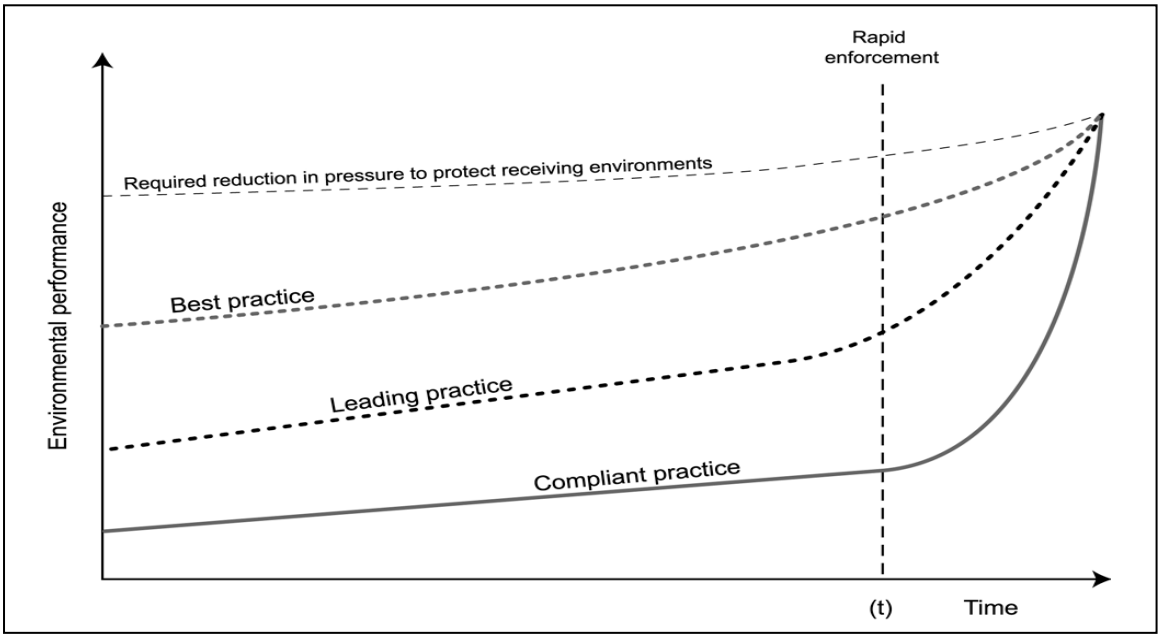

Figure 1-2. Stylistic representation of levels of commitment to reducing environmental pressures

Source: The Natural Edge Project[33]

As illustrated in the figure, at some point in future (i.e. time 't'), market, regulatory and institutional pressures resulting from environmental instability may trigger a period of rapid enforcement which suddenly requires shifting to a much higher level of commitment to environmental performance. The authors suggest that this is the case even for institutions currently operating at what is referred to as 'best practice', given the shortfall in meeting the required reduction in pressure to protect receiving environments.

If this is the case for the higher education sector with regard to embedding sustainability into curricula, then there are clearly decisions to be made in the 'pre-t' period with regard to building capacity within programs and within staff, to make a transition to ESD before or during a period of rapid enforcement. Signs of such enforcement may be evident for example in national government directives for university curriculum (e.g. through a higher education quality assurance framework), national school directives (e.g. through a national schools' curriculum for kindergarten through to year 12) that affect incoming student demands when considering higher education options, and changing employer demands for graduates with particular knowledge and skills.

With this perspective in mind, ESD literature was explored for examples which indicate a timeframe for 't' in the higher education sector. The findings are presented in the following paragraphs.

Over the last two decades there have been growing global calls for change in higher education towards ESD from a variety of sectors within government, business and academia. Table 1-1 summarises a number of declarations and action plans which have been explicit about the need for transitioning to ESD as soon as possible.

Table 1-1. Examples of declarations and action plans promoting ESD

Date	Declaration	Brief Description
1990	Talloires Declaration	The Talloires Declaration is a ten-point action plan for colleges and universities committed to promoting education for sustainability and environmental literacy in teaching, research, operations and outreach at colleges and universities.[34] The role of the university is defined as, *'Universities educate most of the people who develop and manage society's institutions. For this reason, universities bear profound responsibilities to increase the awareness, knowledge, technologies, and tools to create an environmentally sustainable future'*.[35]
1992	Agenda 21	The need for education to play a key role in addressing the challenge of sustainable development was articulated within the global community two years later at the Rio Earth Summit in 1992, with its action plan *Agenda 21*[36] calling for education. This was acknowledged in a range of national planning documentation around the world.[37]
1997	Thessaloniki Declaration	This declaration was made unanimously by 83 countries, relating to education and public awareness for sustainability [38]
1998	World Declaration	UNESCO World Conference on Higher Education produced the *World Declaration on Higher Education in the Twenty-First Century: Vision and Action*, which stated that, *'Without adequate higher education and research institutions providing a critical mass of skilled and educated people, no country can ensure genuine endogenous and sustainable development'*.[39]
2000	Earth Charter	The United *Nations Earth Charter* released in 2000, also provided a general statement of ethics and values for a sustainable future.[40]
2001	Lüneburg Declaration	This declaration was adopted by the GHESP partners (IAU, ULSF, Copernicus Campus and Unesco), on the occasion of the International COPERNICUS Conference, titled 'Higher Education for Sustainability Towards the World Summit on Sustainable Development (Rio+10)'.[41]
2002	Ubuntu Declaration	At the 2002 World Summit on Sustainable Development, this declaration was created for all levels of education, focusing on the need for education and science and technology for sustainable development.[42]

Source: References noted within the table.

Of these declarations, the World Declaration on Higher Education in the 21st Century appears to be the most forthright in the role of universities, stating,

> *'We affirm that the core missions and values of higher education, in particular the mission to contribute to the sustainable development and improvement of society as a whole, should be preserved, reinforced and further expanded, namely, to: (a) educate highly qualified graduates and responsible citizens able to meet the needs of all sectors of human activity, by offering relevant qualifications, including professional training, which combine high-level knowledge and skills, using courses and content continually tailored to the present and future needs of society … Higher education itself is confronted therefore with formidable challenges and must proceed to the most radical change and renewal it has ever been required to undertake.'*

Following the World Declaration and others highlighted in Table 1-1, the *Ubuntu Declaration* together with the *Summit Declaration* of the United Nations Decade of Education for Sustainable Development (DESD, 2005-2014) led by Japan,[43] created a global platform for dialogue in the higher education sector. Since the declaration of the *Decade of Education for Sustainable Development*, there has been a rapid growth of ESD literature about the role of universities in education, research, policy formation and information exchange necessary to make sustainable development possible.

Within this discourse, the UNESCO-based International Association of Universities' working group on Higher Education and Sustainable Development[44] highlights that while most universities and colleges have yet to seriously address sustainability issues, therein lies significant opportunities, particularly in building reputation, for those who are early leaders in contributing toward sustainable development. According to a study undertaken by the American *Campus Sustainability Assessment Project*, leading institutions in this area could be seen to share three important characteristics,

> *"First, these 'sustainability leaders' have adopted serious strategies for systematically addressing the sustainability of the institution. They have policies stating their commitment to sustainability goals, and they have specific plans in place that explain how they intend to achieve them. Second, these institutions have provided the resources needed to implement their sustainability plans. They hire staff, form committees, allocate budgets, and show clear administrative support for sustainability initiatives. Third, these sustainability leaders know where they have been, where they are, and where they are headed in terms of sustainability. They measure and track their progress toward sustainability, and regularly meet and update goals and targets."*[45]

At an institutional level, universities are becoming increasingly vocal about their commitment and achievements with regard to education for sustainable development.

Table 1-2 summarises a number of global alliances between key universities that include a component on ESD for technical professionals. However, despite global recognition of the need and the apparent interest in integrating ESD into higher education, as seen above, there are still very few examples of embedding ESD within the curriculum found in the literature. As Kerr stated in his discussion of the problem of curriculum reform as far back as 1968,

> *'Certainly the rapid social changes resulting from advances in technology and automation and the alarming growth of knowledge are forces which should have influenced the schools – and indeed the universities – long before the present decade'.*[46]

In considering this dilemma for electrical engineering education, Professor Midwinter reflected during his presidency of the Institution of Electrical Engineering (2000-2001) that the general lack of mainstreaming may be because higher education institutions are generally slow to change, with change often eventually forced upon them from the outside.[47] He used the experiences of integrating quality assurance, and computer-aided learning in the United Kingdom as examples.

Despite this lack of progress, there are signs of progress that suggest there is less than a decade before the time 't' noted in Figure 1-2 for ESD in the higher education sector. For example, in 2003 the Australian federal government established the Australian Research Institute in Education for Sustainability (ARIES) program to undertake projects with government, community and business organisations around ESD.[48] In 2005 ARIES published a national review of environmental education and its contribution to sustainability in Australia across a number of sectors including further and higher education.[49] In this report the authors concluded that creating opportunities within the further and higher education curricula is one of the biggest challenges, as learning for sustainability also has implications for institutional culture, management procedures and research actions. In New Zealand, the 2002 *Tertiary Education Strategy* includes sustainability as one of six national development objectives.[50] In South Africa, the 2001 South African Framework emphasizes environmental education for a wide range of education institutions including higher education.[51] In the UK, the federal government's *Sustainable Development Education Panel* required all UK further and higher education institutions to have staff fully trained in sustainability and providing relevant learning opportunities to students by 2010.[52]

Table 1-2. Examples of university alliances promoting ESD

Alliance	Brief Description
Association for the Advancement of Sustainability in Higher Education (AASHE)	AASHE is a member organisation of colleges and universities in the US and Canada working to create a sustainable future, which has many resources to promote sustainability from governance and operations to curriculum and outreach. The *AASHE Bulletin* is the leading news source for campus sustainability in the US and Canada, and *AASHE Digest* is an annual compilation of Bulletin items. AASHE hosts the websites of the Higher Education Associations Sustainability Consortium (HEASC) and the Disciplinary Associations Network for Sustainability (DANS). AASHE has developed a standardised campus sustainability rating system called STARS (Sustainability Assessment, Tracking & Rating System), launched in 2009.
American College & University Presidents Climate Commitment (ACUPCC)	The ACUPCC is an initiative of presidents and chancellors to address global warming by committing to making their campuses climate neutral over time and by providing the education and research to enable society to do the same. Nearly 600 US presidents have signed the commitment and are publicly reporting their progress, including greenhouse gas emission reports and Climate Action Plans. The coordinators include Second Nature, ecoAmerica and AASHE.
Global Higher Education for Sustainability Partnership (GHESP)	Comprising the International Association of Universities (IAU) the University Leaders for a Sustainable Future (ULSF) Copernicus-Campus and UNESCO, GHESP is working to mobilise universities and higher education institutions across the planet to support sustainable development, in response to Chapter 36 of *Agenda 21*.
Higher Education Partnership for Sustainability (HEPS)	A three-year partnership (2001-2003) of 18 United Kingdom Higher Education institutions committed to sustainability supported by the funding councils of England, Northern Ireland, Scotland and Wales. Co-ordinated by Forum for the Future the partnership worked to generate transferable tools, guidance and inspiration, to demonstrate the potential the integrating sustainability in the higher education sector. This included cutting carbon emissions, building 'sustainability literacy' and deploying their combined buying power of over 3 billion pounds (AUD$5 billion) in favour of fair trade and ethical investment.[53]
Research in Higher Education for Sustainability	UNESCO, in association with the International Association of University Leaders for a Sustainable Future (ULSF) International Association of Universities and a number of other organisations including the United Nations University, has held a number of meetings to discuss and explore the future of research into 'higher education for sustainability', including the 2005 *Halifax Consultation* and a joint UNESCO-UNU 2006 Workshop on 'Setting the Stage for a Strategic Research Agenda for the UNDESD'.[54]
University Leaders for a Sustainable Future (ULSF)	ULSF serves as the Secretariat for signatories of the Talloires Declaration, a ten-point action plan committing institutions to sustainability and environmental literacy in teaching and practice. Over 350 university presidents and chancellors in more than 40 countries have joined by signing the declaration.

Source: References noted within the table.

In conclusion, the following comments are made about the context for curriculum renewal in higher education:

- Globally there is growing knowledge and awareness amongst the community about issues which will dominate the 21st Century, including climate change, loss of biodiversity, availability of water and other resources, sea level rise, and the impacts of a wide range of pollutants.
- The literature suggests that within society, expectations are already rising with regard to higher education delivering 'education for sustainable development' (ESD).
- The literature suggests that within the next decade there are likely to be abrupt market, regulatory and institutional shifts responding to global challenges (i.e. time 't'), which will require professional graduates to be equipped with a range of new knowledge and skills.
- In such challenging times, there appears to be an emerging consensus among the higher education community, that professional education will need to be significantly renewed in the coming decade to align with the requirement to meet these graduate needs, presenting a significant challenge to the education sector in deciding how to educate its students.
- However, despite awareness of the need for curriculum renewal towards ESD for more than 20 years, there has been a distinct lack of action within the higher education sector to achieve this outcome. Although there are signs of change, progress on the whole is still limited to examples rather than being mainstreamed across the sector.

From the literature it is concluded that there is a significant need for ESD within the higher education sector. Furthermore this change is urgent, in order to equip professionals with the knowledge and skills required to address 21st Century challenges, and to contribute to sustainable solutions within the next couple of decades.

1.2 The need for curriculum renewal in engineering education

Engineering is a key component to any industrialised nation; however the engineering profession has also played a key role in facilitating the kinds of activities that have brought about human induced climate change. Hence, the need for engineers with the right knowledge and skills to address the challenges facing society today is crucial. In the following paragraphs the changing role of engineering is discussed, along with the necessity for timely – or 'rapid' – curriculum renewal towards engineering education for sustainable development (EESD), as well as the lack of progress to-date and the subsequent time lag dilemma facing engineering educators.

The role of engineering is experiencing the most dramatic shift in knowledge and skills since the industrial revolution. Discourse and inquiry at a national level relating to this changing role has grown significantly in the last decade. For example, in Australia modelling by the CSIRO has shown that three million Australians (of a population of around 22 million), will need training or re-training in energy efficiency, green building technologies, sustainable energy and more sustainable agricultural systems to enable Australia to achieve the IPCC's recommended targets for greenhouse gas reductions.[55] Furthermore, surveys are highlighting that the state of knowledge, understanding and implementation of even basic environmental and energy management systems in the business sector is poor. A 2008 survey of 300 Australian business CEOs regarding operating in a carbon-constrained economy found that two-thirds (67 percent) of businesses were concerned or unsure about compliance obligations, and only a handful of businesses (less than 3 percent) had implemented a strategic response to climate change.[56] A 2007 survey of the Australian mining and metals sector also highlighted an alarmingly slow adoption of energy demand management practices, with nearly half (43 percent) of companies still not having implemented an official energy policy.[57] In the same context, only 10 percent of companies responding to a 2007 national Australian Industry Group survey on climate change practices felt informed enough to manage the risks associated with climate-related impacts.[58]

Professional organisations around the world have been declaring an urgent need to keep up with the pace of change and forming collaborations to make progress, in particular since the early 1990s. For example, in 1992, together with the International Union of Technical Associations and Organizations (UATI) and the International Federation of Consultant Engineers (FIDIC), WFEO created the World Engineering Partnership for Sustainable Development (WEPSD),[59] which has since been active in promoting a new vision for 21st Century engineering.[60] In 1998, Wm Wulf, then President

of the American National Academy of Engineering, echoed these international sentiments in the following statement to a national forum,

> *'Growing global competition and the subsequent restructuring of industry, the shift from defence to civilian work, the use of new materials and biological processes, and the explosion of information technology … have dramatically and irreversibly changed how engineers work. If anything, the pace of this change is accelerating ... The half-life of engineering knowledge - the time in which half of what an engineer knows becomes obsolete - varies by field, but is estimated to be in the range of 2.5 to 7.5 years.'*[61]

Professor Wulf's statement and the aforementioned action is supported by a wealth of literature which suggests it is very likely that 21st Century engineering will have little to do with creating fossil fuel-based products and services.[62,63,64,65,66] As Australian engineer and 2009 WFEO president and former president of Engineers Australia Barry Grear (AO) questions,

> *'What aspirational role will engineers play in that radically transformed world?'… An ever-increasing global population that continues to shift to urban areas will require widespread adoption of sustainability. Demands for energy, drinking water, clean air, safe waste disposal, and transportation will drive environmental protection [alongside] infrastructure development'.*[67]

Until the mid-20th Century, engineers generally chose from two or three aspects of manufacturing: i.e. making a product well, making it quickly, and making it inexpensively. In the 21st Century, there are two more emerging criteria: that of making it safely and making it environmentally benign.[68] Furthermore, engineers are now expected to quickly find solutions to a range of emerging development challenges such as the need to reduce greenhouse gas emissions to mitigate climate change, and to assist humanity to adapt to climate change impacts, such as changing weather conditions, rising sea levels and stronger and more frequent natural disasters. Engineers are expected to retrofit, redesign and innovate new products and services that meet rapidly increasing environmental and social criteria, while also dealing with the reducing availability and increasing costs of conventional inputs such as oil and some metals, higher standards on waste and pollution, all the while being cost effective. Hence, while knowledge and skills in areas such as thermodynamics, fluid mechanics and structures will still be required, knowledge and skills in areas such as energy systems, chemical engineering, built environment, electricity production, engines and combustion processes and water supply and treatment will change significantly.

Such changing knowledge and skills can be illustrated in the area of water sanitation. The current solution for most urban populations is still a 'flush and forget' system which uses substantial volumes of potable water to wash human waste away, preferably into a sewer system, where it may either be treated by an (often energy-intensive) waste-water treatment plant, or not treated at all, before being discharged into the local waterway. Lester Brown reflects that,

> *'The one-time use of water to disperse human and industrial wastes is an outmoded practice, made obsolete by new technologies and water shortages. Water enters a city, becomes contaminated with human and industrial wastes, and leaves the city dangerously polluted. Toxic industrial wastes discharged into rivers and lakes or into wells also permeate aquifers, making water – both surface and underground – unsafe for drinking'.*[69]

In the late 19th Century, this method of sanitation transformed urban living by reducing disease and death. However, on a global scale it is now outdated, expensive and resource intensive, dispersing pathogens and pollution throughout major waterways and actually contributing to disease and death in developing countries. The engineering profession clearly has an opportunity to evolve water sanitation practices, potentially saving significant amounts of water in the process.

There are also good examples of engineering sustainability innovations emerging around the world, including products such as the white light emitting diode (LED) light bulb,[70] materials advances such as non-petrochemical organic based carpets developed by major carpet provider *Interface Carpets*, green buildings such as Malaysia's Zero Energy Office (ZEO) building,[71] and large-scale green developments such as the planned 8,800 hectare 'eco-city' of Dongtan near Shanghai's airport, which will use recycled water, co-generation and biomass for energy, and which is striving to be as carbon-neutral as possible.[72]

In addition, Dr Sharon Beder from the University of Wollongong makes the point that engineers now often move into management, policy and government, financial institutions, and not simply traditional engineering careers. Hence engineers have the potential to make a considerable contribution to sustainable development across many sectors of society if, as the World Federation for Engineering Organisations (WFEO) emphasise, they are equipped with the relevant knowledge and skills to address society's most significant issues.[73]

Despite the rapid growth in discussion about the need for engineering education to incorporate sustainability knowledge and skills, an internet search of definitions did not

provide any documented definitions for the widely used term 'engineering education for sustainable development' (EESD); nor any definitive lists of desired competencies, graduate attributes or learning outcomes. However, according to the World Federation of Engineering Organisations (WFEO, representing 15 million engineers from more than 90 nations) for engineers, EESD means education that encourages engineers to play, *'an important role in planning and building projects that preserve natural resources, are cost-efficient and support human and natural environments'.*[74] Hence from this statement, EESD is considered a broad area covering technical, social and economic aspects.

There is a growing volume of engineering education literature on the topic of sustainability and what EESD should comprise within the engineering curriculum, including content and pedagogical practices. Over the last 10 years discourse has moved from attempting to understand the term 'sustainability' as it relates to environmental education, social science, higher education (for example authors such as Sauvé,[75] Fien,[76] Leal,[77] Sterling,[78] Corcoran and Wals,[79] Parkin *et al*[80], Cortese,[81] Blewitt and Cullingford,[82]and Dawe *et al*[83]), and the engineering profession (for example Jansen,[84] Mulder,[85,86] Ferrer-Balas *et al*[87], Holmberg *et al*[88]), to attempting to understand what knowledge and skills graduate engineers should be equipped with (for example Carroll,[89] Cortese,[90] Crofton,[91] Ashford,[92] Azapagic *et al,*[93,94] McKeown *et al,*[95] Pritchard *et al*[96] and Allenby *et al*[97]), how EESD should be taught with regard to pedagogical practices (for example Timpson *et al*[98] on tips for integration, Newman and Fernandez[99] who discuss institutionalising such curriculum renewal, Steinemann[100] and Lehmann *et al,*[101] who write about problem based learning, and Crawley *et al*[102] who discussed the need for sustainable development to form a framework within which engineering education needs to be rethought), and the larger education agenda (for example Rowe who discusses policy direction,[103] Stephens and Graham[104] who discuss research needs, Steinfeld and Takashi[105] who discuss the challenge of trans-disciplinarity, and Holdsworth *et al*[106] who discuss the need for professional development for ESD).

Internationally, a number of professional organisations have also undertaken reviews on the topic, such as the 2005 American National Academy of Engineering (NAE) report on educating the engineer of 2020,[107] the 2006 UNESCO workshop on Engineering Education for Sustainable Development,[108] the 2007 UK Royal Academy of Engineering (RAE) report on educating engineers for the 21st Century,[109] the Higher Education funding Council for England (HEFCE) *Strategic Review of Sustainable Development in Higher Education in England,*[110] and the Chinese Academy of Engineering.[111]

There are also numerous authors writing about local experiences in trying to embed EESD within their own universities around the world, as highlighted in Table 1-3.

Table 1-3. Examples of papers on EESD initiatives

Country/ Region	Example author and institution details
Europe	Kamp[112] and Mulder[113] in Netherland's Delft University; Lundqvist *et al*[114] in Sweden's Chalmers University; Fenner *et al*[115] in the UK's Cambridge University; Humprhies-Smith[116] in the UK's Bournemouth University; Lozano[117] in Wales' Cardiff University; Fletcher *et al*[118] in England's Aston University; Ferrer-Balas *et al*[119] in Spain's Technical University of Catalonia.
America	Allenby *et al*[120] national overview; Epstein *et al*[121] in the Massachusetts Institute of Technology; Mihelcic *et al*[122] in Michigan Technical University;
South America	Lozano-Garcia *et al*[123] in ITESM Monterrey; Wright *et al*[124] writing about the collaboration between Michigan University and Chile's University of Concepción
Asia	Onuki and Takashi[125] in Japan's University of Tokyo; Uwasu *et al*[126] in Japan's Osaka University; Kuangdi[127] in a Chinese national overview.
Africa	Olorunfemi and Dahunsi[128] in Lagos State Polytechnic and the University of Ibadan, Nigeria; Ramjeawon[129] in the University of Mauritius.
Australia	Davis and Savage[130] in Queensland University of Technology, Goh[131] in the University of Southern Queensland, Bryce *et al*[132] in the University of Technology Sydney, Mitchell[133] in the University of Sydney; Carew and Therese[134] in the University of Wollongong; Koth and Woodward[135] in the University of South Australia; Daniell and Maier[136] in the University of Adelaide; Carew and Lindsay[137] in the University of Tasmania and Curtin University;[138] Mann and Smith in computing engineering.[139]

Source: References noted within the table.

Within the literature highlighted in Table 1-3, there are many references to ensuring that engineers have a good understanding of: global systems and ecosystem principles; economic, social and environmental risks; impacts and opportunities associated with their engineering solutions; and knowledge and skills in sustainable development related tools and technologies. Further to this, authors such as Pérez-Foguet *et al*[140] also discuss the need to incorporate developing country issues into engineering studies, and authors such as Boyle,[141] Steinfeld and Takashi,[142] Kumazawa *et al*,[143] and Mihelcic *et al*[144] present an emerging field of 'Sustainability Science' as a way to describe what should be taught in EESD, which incorporates the notion of transdisciplinarity, and which integrates industrial, social, and environmental processes in a global context.[145]

With this literature in mind, proposing that current engineering education is not sufficiently preparing graduates to meet society's needs is quite a bold assertion that requires serious consideration, beginning with an appreciation of the extent of literature available on this topic. For the purpose of this study and in the absence of consensus about what EESD should comprise, all of the above considerations are assumed to be valid components of EESD, producing a substantial body of work. However, the extent of

literature on a number of important related topics is lacking. For example, there is an absence of rigorous study on the relative role of the engineering profession in addressing climate change and sustainable development, in comparison to other professions in the global community, or on the importance of interdisciplinary and multidisciplinary action. There are also few academic studies focused on whether shifting expectations necessitate a shift in the knowledge and skills needed to practice as a professional engineer. Furthermore, there appear to be no studies comparing success in student recruitment or departmental viability for those departments who incorporate EESD against those who don't. There is also a lack of data assessing relationships between career success for engineers with and without sustainability related capabilities. In such a rapidly emerging field these 'gaps' in academic literature are problematic, but do not prevent further exploration of the topic.

In summary, despite the growth in literature on the need for EESD, there has not yet been a rigorous global review of this discipline undertaken by any single organisation or collaboration. Conference themes and journal topics have tended to focus on issues affecting the ability of engineering education to be changed (i.e. organisational, resourcing, funding, timeframe and content issues), rather than the extent to which the curriculum has changed. Within EESD literature, the most prolific papers have been on the topic of single champions or teams discussing individual initiatives in the subject area of EESD. Some papers have documented the success of strategically embedding case studies and flagship courses (predominantly in first year, and at post-graduate level as discussed in Chapter 3), and few papers have discussed methods to integrate sustainability theory, knowledge and application across programs and across disciplines.

In the absence of such a reference point, the state of EESD is also explored through considering a number of surveys that have been undertaken over the past decade, as summarised in Table 1-4, in addition to various reports emerging from engineering professional and academic bodies internationally. A number of indicators are also discussed that relate to drivers for, and impediments to, EESD.

Table 1-4. Summary of key surveys on the state of EESD

Year	Survey	Brief Description
1998	World Engineering Partnership for Sustainable development	Questionnaire circulated to national members of WFEO to provide an improved benchmark. Conclusion: No strong or consistent approach to environment and sustainable development in engineering education. On a country average, not much more than 10 per cent of time in 10 per cent of courses is devoted to these aspects.[146]

Year	Survey	Brief Description
2000-2002	University of Surrey (UK) and University of Melbourne (Australia)	Survey of a sample of international engineering students on their level of knowledge and understanding of sustainable development; the first of its type.[147] Conclusion: (21 respondents from 40 invitees) The level of sustainable development knowledge is not satisfactory, and significant knowledge gaps exist within the curriculum.[148]
2002	Royal Melbourne Institute of Technology	Twenty-one Australian universities invited to participate in a survey on the status of ESD in these institutions. Conclusion: (from a quarter of invitees) Few universities are engaged in such education for a wide range of their students. In some universities more students of particular disciplines are gaining exposure. However, there are clear barriers to the introduction and expansion of sustainability education.[149]
2006	Chalmers University of Technology, Delft Technical University, Technical University of Catalonia, Alliance for Global Sustainability	The Observatory assessed the status of EESD in European Higher Education, benchmarking 51 European Universities (survey), against examples from outside Europe. Conclusion: To-date there is no European University that shows sufficient progress in EESD to be considered an inspiration.[150]
2007	Forum for the Future's Engineers of the 21st Century Programme	499 young engineers (online) who had graduated between 1997 and 2005 surveyed regarding sustainability literacy.[151] Conclusion: 40 percent perceived their university lecturers had inadequate knowledge of sustainability. 30 percent perceived their lecturers had a positive to passionate attitude about ESD.
2007	National Framework for Energy Efficiency[152]	National survey on the state of engineering education in Australia, within the sub-topic of energy efficiency education. Conclusion: The state of education for EE in Australian engineering education is currently highly variable and ad hoc across universities and engineering disciplines. Key issues for educators included perceived course overload, and lack of time for professional development or to prepare new content.
2007-2008	US Centre for Sustainable Engineering	Benchmarking survey on the extent of sustainable engineering education within 1,368 engineering departments (or the equivalent), with just over one fifth of the invited 364 American universities and colleges participating.[153] Conclusion: The engineering education community is now at a critical juncture. To-date, there has been a significant level of 'grass-roots' activities but little structure or organisation. The next step will be for engineering accreditation bodies to think critically about what should or should not be included.[154]
2008	Chalmers University of Technology, Delft Technical University, Technical University of Catalonia, Alliance for Global Sustainability.	Second survey by *The Observatory*[155] initiative. Of the 57 universities participating in the 2008 survey, most had not participated in the 2006 survey, making it difficult to directly compare the results of the successive reports. Conclusion: A growing number of institutions from European countries are actively engaged in sustainability activities.

Source: References noted within the table.

The results of these surveys suggest that in general the curriculum renewal process to-date has been slow and *ad hoc*. This conclusion is supported by the findings of researchers in the field such as Ferrer-Balas *et al,*[156] Lozano *et al,*[157] *and* Mulder *et al*[158] and numerous other authors writing for conference proceedings from key engineering education research events and conferences around the world over the last decade.[159] Furthermore, as mentioned above, internationally there are a number of publications arriving at similar conclusions by the American National Academy of Engineering (NAE),[160] UNESCO,[161] the UK Royal Academy of Engineering (RAE)[162] and the Higher Education funding Council for England (HEFCE).[163]

In Australia, the 2007 Australian Learning and Teaching Council (formerly the Carrick Institute) report on addressing the supply and quality of engineering graduates for the 21st Century[164] also concurred with these international reports, highlighting a lack of progress since the 1997 report, *Changing the Culture*[165] which had raised concerns with regard to curriculum change and graduate attributes. Lead author Professor Robin King concluded,

> *'… there is not strong evidence that this [curriculum renewal] is being achieved in a systematic and holistic sense. Few engineering education programs are underpinned by a comprehensive specification of program objectives and detailed graduate outcomes that provide a clear understanding of the knowledge, attributes and capability targets for graduates in the particular discipline'.*[166]

In the 2008 report, the authors identified that although there is willingness among leading engineering educators to address emerging issues, there are too few examples of a systematic, 'top-down' educational design and/or review process where learning experiences and assessment measures are rigorously mapped and tracked against the specification of graduate outcomes for a particular program.

1.3 Drivers affecting the progress of EESD

In order to gain further insight into the discourse on EESD, it is useful to appreciate both the pressures driving curriculum renewal, and pressures that might be limiting curriculum renewal. Hargroves and Smith[167] use two 'Drivers for Change' diagrams to highlight a number of systemic pressures – or 'drivers' – for and against sustainable practice as shown in Figure 1-3 (a) and (b).

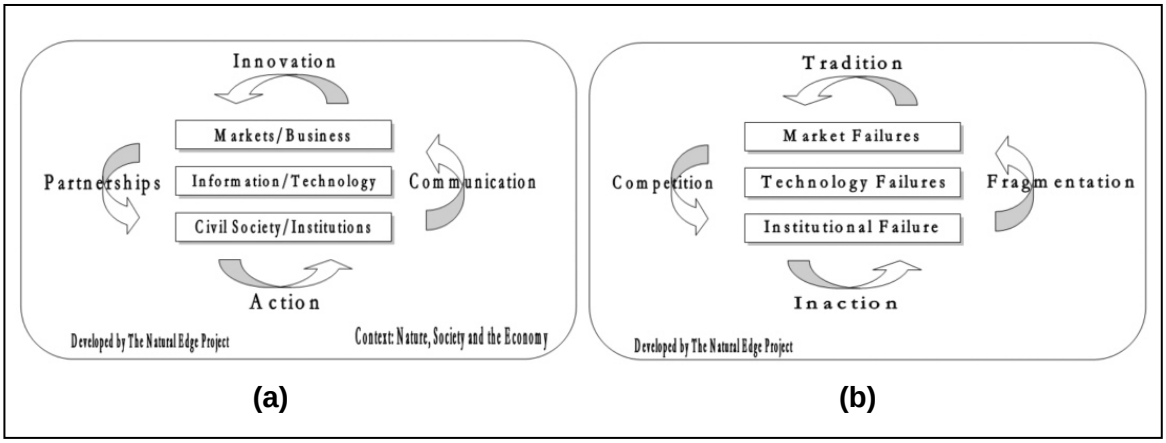

Figure 1-3. Platform for Change Diagrams, depicting (a) drivers that are promoting sustainable outcomes; and (b) drivers that are restricting sustainable outcomes

Source: (a) Hargroves and Smith;[168] (b) Hargroves and Smith[169]

These two diagrams present a holistic framework to interrogate the literature, in particular with regard to the consideration of market, information and institutional perspectives. They show how drivers promoting change may be evident in discourse about including innovation, partnerships, action and communication, while drivers limiting change may be discussed using language such as tradition, competition, inaction and fragmentation. Hence, these diagrams are now used as a framework to review the literature for more understanding about the state of EESD, beginning with drivers that are promoting change.

Reports such as the Higher Education Funding Council for England's 2006 report on the 'Barriers and Challenges to Education for Sustainable Development'[170] suggest that although actual progress in curriculum renewal has been slow for engineering education, there *is* increasing pressure for curriculum renewal towards EESD from a range of factors. This includes pressure from the 'top down' (for example from accrediting institutions, professional organisations, education institutions and government) and from the 'bottom up' (for example from potential employers, and the faculty members and students themselves). Table 1-5 provides a brief explanation of the drivers that are promoting EESD, as cited in the literature, followed by explanations below.

Table 1-5. Summary of key drivers that are promoting EESD

Driver	Factors promoting engineering education for sustainable development
Market/ Business	– *Shifting requirements by potential employers* - increasing requirements for engineers to practice in accordance with tightening legislation. – *Increasing student demand and market potential* - students seeking sustainable development content within their institutions of study.
Information/ Technology	– *Increasing faculty interest in related research and teaching innovation* – increasing incentives by governments and international organisations. – *Increasing focus in declarations and conference action plans* - creating benchmarks for new kinds of engineering professionals.
Institutional/ Civil Society	– *Increasing professional advocacy* - with leaders stating the pivotal role of engineering in addressing 21st Century challenges. – *Shifting requirements for practicing engineers by professional organisations* - where code of ethics statements and codes of practice are being updated. – *Shifting accreditation requirements for graduate engineers* - formalising sustainability knowledge and skill requirements. – *Increasing commitment and action by highly regarded university peers* - increasingly vocal commitments and alliances.

Source: References noted within the table.

Further to identifying a drivers promoting EESD, a number of key drivers were found in the literature which appear to be limiting efforts of engineering educators to undertake significant and rapid engineering curriculum renewal, as summarised in Table 1-6 and discussed in more detail in the following paragraphs.

Table 1-6. Summary of key drivers that are limiting progress towards EESD

Driver	Factors limiting engineering education for sustainable development
Market/ Business	– *Persistent 'old economy' industry practices*, wherein employers continue to employ graduates to undertake unsustainable practices. – *Perceived threat to employability and position*, posing a threat to employability and retraining investments. – *Short-termism in the Higher Education Institution (HEI) sector*, where short-term pressures demand increasing quarterly profit results. – *A shortage of engineering graduates,* in a 'take what you can get' scenario.
Information/ Technology	– *Growing disconnect between engineering and science*, where engineering professionals may not be 'in-step' in understanding complexity. – *Lack of convenient access to emerging and rigorously reviewed information*, where academics may have difficulty getting information or be overwhelmed. – *Lack of access to information in foreign languages*, which may impede the integration of emerging technologies and innovations.
Institutional/ Civil Society	– *Lack of strong requirements for change*, where there is a lack of certainty about current and future legislative requirements and support. – *Lack of academic staff competencies in EESD*, with a relatively low rate of professional development among educators.

Source: References noted within the table.

1.3.1 Drivers promoting EESD in market/ business

- ***Shifting requirements by potential employers:***

  There are increasing requirements for engineers to practice in accordance with tightening legislation and regulations, in addition to potential future requirements, across all sectors.[171] For example, over the last 30 years many industrialised nations have moved to regulate the generation and disposal of toxic wastes and remediation of contaminated sites. With market globalisation, regulations such as the European Union's Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS) Directive[172] and the Waste Electrical and Electronic Equipment (WEEE) Regulations[173] are now affecting factories and supply chains in developed and developing countries alike.

  Industry is also acting to address future risks associated with new legislation, regulation and taxation policy affecting engineering practice, including future controls for greenhouse gas emissions and carbon trading schemes to address climate change. For example, the World Business Council for Sustainable Development (WBCSD) was formed in 1992 and now consists of more than 200 companies from more than 20 major industrial sectors including many engineering disciplines.[174] In 2007 at the UN Global Compact Leaders Summit in Geneva, chief executives of 153 companies committed to speeding up action on climate change and called on governments to agree as soon as possible on measures to secure workable and inclusive climate market mechanisms post 2012, when the Kyoto Protocol expires. Signatories to the statement, including 30 from the Fortune Global 500, commit their companies to take practical actions to increase the efficiency of energy usage and to reduce the carbon burden of products, services, and processes, to set voluntary targets for doing so, and to report publicly on those targets annually.[175]

  Increasingly companies are committing to dealing with the climate issue strategically and to building relevant capacity. Jeroen van der Veer, Chief Executive, Royal Dutch Shell reflects that in this rapidly changing environment, re-engineering engineers' is a challenge.[176] Jonathon Porritt, chairman of the UK Sustainable Development Commission and Founding Director of the UK's *Forum for the Future*, told a 2007 Global Sustainability Forum on the Future for Engineering Education,

"Big companies now are saying, 'if you can't give us engineers who understand the centrality of sustainable issues and understand the importance of what are sometimes called soft skills ... then you're not giving me the type of engineer that I need.'"[177]

- ***Increasing student demand and market potential:***

  While institutions grapple with the prospect of embedding sustainability within engineering education, there are emerging signs that the consumers of education – the students themselves – are seeking sustainable development content within their institutions of study.[178,179] Sustainability vocabulary is increasingly being used as a marketing device on engineering department websites and through program descriptions in recruitment handbooks and there are a number of initiatives taking advantage of this market potential, as summarised in Table 1-7.

Table 1-7. Examples of increasing student demand and market potential

Example	Brief Description
Conference	At the second International Federation of Engineering Education (IFEES) conference held in collaboration with the *2008 7th Global Colloquium on Engineering Education*, the 'Global Student Forum Working Session' focused on 'Sustainability and Engineering Education' where participants joined 90 global student leaders participating in the Global Student Forum to, '*discuss solutions related to Sustainability of Engineering Education, Sustainability in Engineering Education, and Sustainability through Engineering Education'.*[180]
Survey	A survey undertaken as part of the Royal Academy of Engineering and Forum for the Future's Engineers of the 21st Century programme (E21C) found that almost two thirds of the 499 graduates surveyed online felt sustainability was either important or very important to their job role today, with more than 90 percent of the respondents wanting to do more than scratch the surface of the topic and instead understand the impacts of their decisions in addition to practical methods of incorporating sustainability into their work.[181]
College guide	In the US, the American *2009 Kaplan College Guide* is focused for the first time on environmentally responsible schools and green careers, featuring 25 'Green Colleges' and 10 'Hot Green Careers'. The editors consulted a wide array of constituents, including admissions directors, parents, students, and professionals. To compile the hottest green careers list, Kaplan surveyed the course of study of hundreds of undergraduate students, then compared selections against the fastest-growing, most competitive global industries tracked by the US Department of Labor.[182]
Learning and teaching program	The Faculty of Engineering at Imperial College London initiated the *EnVision* programme to promote excellence in teaching, learning and academic leadership, focusing on students making links between careers (in engineering) and aspirations of 'making a difference to the world'.[183] EnVision activities include the set-up and support of projects which enable students to experience aspects of sustainable engineering, interdisciplinary work and real-world issues. Senior lecturer Esat Alpay reflects that, *'Sustainable engineering is promoted through initiatives such as the 'Engineering Impact' series of lectures by eminent speakers on issues such as climate change, health, energy and design, with the aim of inspiring students towards the engineering profession and their potential impact on society as future engineers'*.[184]

Source: References noted within the table.

Michelle Grant, Program Director for the 'Youth Encounter on Sustainability' program at ETHZurich, reflects that there is a growing personal awareness among university level students to the global challenges, due in part to increased media exposure, increasing globalisation, study exchange programs and youth driven initiatives.[185] Discussing the growing concern for the future and interest in sustainable development among today's youth the Head of Engineering Sciences at UNESCO, Dr Tony Marjoram, writes that, *'… we need to emphasise these issues in teaching curricula and practice'.*[186] This type of action is also being encouraged in highly regarded HEIs internationally. For example, the organisation Engineers for a Sustainable World which has a primary goal to, *'infuse sustainability into the practice and studies of every engineer'*, was borne out of Cornell University through its students in 2001.[187]

1.3.2 Drivers promoting EESD in information/ technology

- ***Increasing faculty interest in related research and teaching innovation:***

  There are growing incentives provided by federal governments and international organisations for engineering academia to engage in sustainability research, which have begun to filter through to course development. As highlighted by the Australian 2007 report, 'Addressing the Supply and Quality of Engineering Graduates for the New Century', governments are expecting university-based engineering research to be contributing towards innovation, ultimately providing economic value and contributing to solving environmental, security, healthcare and other significant problems.[188] Research funding opportunities are appearing across the disciplines, from sustainable design and practice to research in engineering education for sustainable development itself. By the very nature of academic positions, faculty are required to integrate their research into the courses that they teach (i.e. research-led teaching). The number of dedicated research institutes and centres focused on sustainable development has rapidly grown over recent years. Furthermore, a range of student initiated networks such as 'Australian Campuses Towards Sustainability' and 'Students for Sustainability' have been formed.

  Within the engineering higher education sector, there are already a significant number of institutes, centres, and collaborations addressing sustainable design and practice, including: Rocky Mountain Institute in Snowmass, Colorado; the Pew Climate Centre on Global Climate Change in Arlington, America; the Climate Group, with its head office in London, United Kingdom; the Wuppertal Institute for Climate, Environment and Energy in Wuppertal, Germany; and the Energy and Resources

Institute (TERI) in New Delhi, India, which annually hosts the Delhi Sustainable Development Summit (DSDS) chaired by the TERI Director General, and President of the Intergovernmental Panel on Climate Change, Professor Rachenda Pachauri. Additionally, the Cambridge University Engineering Department's Centre for Sustainable Development was established in 2000, following support provided by the Royal Academy of Engineering to introduce concepts of sustainability in undergraduate engineering courses.

- ***Increasing focus in declarations and conference action plans:***

  A plethora of declarations and action plans were found during the literature review. However, such documents are not necessarily significant drivers by themselves, or a measure of actual progress with regard to the state of EESD. As many declarations and action plans are non-binding agreements, there is potentially little impetus for the institution to make progress if there is not support from the initiators or accrediting bodies. In addition, signatories can be lulled into a false sense of achievement and this can actually lead to reduced progress. Professor Don Huisingh, Editor-in-Chief of Elsevier's Journal of Cleaner Production reflects that it is evident many signatories are doing very little that can be traced back to declarations or action plans.[189]

  However, such documents can still be useful indicators of increasing awareness among faculty, staff and students. In Table 1-8 a number of often referenced declarations and action plans targeting engineering education from technical institutions, professional organisations and university alliances are highlighted. Most include a preliminary discussion on the importance of professional capacity building to address 21st Century challenges and a call for the higher education sector to re-orient its teaching as a matter of priority.

Table 1-8. Examples of declarations and action plans for EESD

Year	Declaration/ Action	Brief Description
1991	Arusha Declaration[190]	This declaration by the WFEO on the future role of engineering was developed from a study in 1987 by the World Commission on Environment and Development, titled *Our Common Future*,[191] and other documents. The declaration called for specific actions by government, industry and individual professional engineers in their projects, stating *'that education on the issues involved in sustainability be given the highest priority'*.
1994	Engineering Education Workshop (Asia/Pacific) New Zealand[192]	An international workshop of educators from the Asia Pacific region examined 'Fundamentals of Environmental Education in Engineering Education', finding that *all* engineers need to be environmentally educated so they understand the issues involved in sustainable development

Year	Declaration/ Action	Brief Description
		and cleaner production. A holistic approach is needed, including a appropriate attitudes, skills and knowledge, systems skills, interaction skills, broad knowledge in specific areas, and exposure to significant issues.
1997	United Nations Environment Programme Industry and Environment Centre (UNEP IE), WFEO, the World Business Council for Sustainable Development (WBCSD) and the French Ecole des Ponts	Attendees at a joint conference in Paris on the topic of 'Engineering Education and Training for Sustainable Development' concluded that many practising engineers currently have no education in sustainable development, and that sustainable development should in future be included in both undergraduate and post-graduate courses. They also concluded that because the transition to sustainable development must be made in the next 20 years, major changes will be required in ongoing education and practising professionals will need retraining.[193]
1997	American Society of Engineering Educators – International Conference[194]	Attendees at the ASEE conference identified technology in engineering education (the virtual university), sustainable development, and the impact of globalisation on engineering as the primary influences on future engineering education. They also recommended specific action to guide curricula, provide teaching materials, and develop networks.
2002	WFEO Statement on Engineers and Sustainable Development[195]	Representatives of the American National Academy of Engineering met with representatives of the major American engineering organisations to consider how to unify American engineers in support of the goals of the 2002 World Summit on Sustainable Development in Johannesburg, South Africa and to work together after this conference. The group adopted a statement on engineers and sustainable development.
2004	Barcelona Declaration on Engineering Education for Sustainable Development	The 2004 conference declaration of the biennial international Engineering Education for Sustainable Development ('The Declaration of Barcelona') states that, *'Engineering has responded to the needs of society and without a doubt, today's society requires a new kind of engineer…There is evidence that sustainable development has already been incorporated in engineering education in a number of institutions around the world ...'*.[196]
2004	Shanghai Declaration on Engineering and a Sustainable Future	The World Engineers' Convention (WEC2004) in Shanghai had the theme 'Engineers Shape the Sustainable Future'. The Declaration called upon the engineering community, governments and international organisations to promote engineering for our sustainable future, proclaiming, *'Engineering and technology are vitally important in addressing poverty reduction, sustainable development and the other UN Millennium Development Goals, and need to be recognized as such'*.[197]

Source: References noted within the table.

From a qualitative review of mainstream international and regional engineering conference programs spanning the last 5 years (including the Australasian Association of Engineering Education annual conferences, the Global Colloquia on Engineering Education, and the International Conference on Engineering Education) it is clear that major engineering forums are now featuring engineering education for sustainable development as a theme for submission and presentation. Topics covered in submitted papers include issues affecting the ability of engineering education to be changed, including for example organisational issues, resourcing issues, personality issues, funding issues, timeframe issues, and content issues. Papers discussing overstretched resources and declining student intake into environmental disciplines are common features within the programs. Some of the papers appearing in such conferences document success, including case studies and flagship courses (first year, and masters level) but these efforts are rarely documented as part of a longer term strategic plan for curriculum renewal.

Recently there has also been a shift in some global 'mainstream' engineering education conferences, with regard to the themes and requests for papers. For example, the 2008 *7th Global Colloquium on Engineering Education* (GCEE) theme was 'Excellence and Growth in Engineering Education in Resource Constrained Environments', with a research track focused on 'Inferring and Designing Engineering Education Practice from Research and Societal Context: To what extent should engineering educators collaborate globally to re-engineer their programs?'.[198] However, although the 2008 International Conference on Engineering Education (ICEER) theme was 'New Challenges in Engineering Education and Research in the 21st Century' including invited topics on environmental challenges and the role of Engineering Education in Sustainable Development, only two out of more than 235 presentations, and three out of more than 65 posters explicitly addressed either of these topics, and these were case studies.[199]

1.3.3 Drivers promoting EESD in civil society/ institutions

- ***Increasing professional advocacy:***

  Within the rapidly changing global landscape discussed above, senior government and industry leaders around the world have been discussing the prominent role of engineering in addressing such 21st Century challenges for the last decade, as summarised in Table 1-9.

Table 1-9. Examples of professional advocacy in EESD

Year	Organisation	Statement
1997	World Federation of Engineering Organisations (WFEO)	The Engineer's Response to Sustainable Development: *"… Engineers around the world understand that they have a tremendous responsibility in the implementation of sustainable development. Many forecasts indicate there will be an additional five billion people in the world by the middle of the 21st century. This future 'built environment' must be developed while sustaining the natural resources of the world and enhancing the quality of life for all people."*[200]
2004	Engineers Australia	*'It is up to engineers* [and indeed all professions] *to consider sustainability in every project we design and construct and every product that is made. Sustainability is now a fundamental responsibility that we must carry every day … As the national leader of the peak body representing engineers and engineering in Australia I call on all engineers to assume this responsibility – we must quickly learn about sustainability and adapt it into every aspect of our practice - for without engineers 100 percent participation, sustainability will just not happen and severe climate change is inevitable'.*[201]
2007	UK Royal Academy of Engineering	*'Engineering is the practical means by which our greatest challenge will be solved, such as* [sustaining] *the environment, reducing poverty, and* [increasing] *health and wellbeing. We engineers are trained and practised at looking in two directions at once – both at science and at business and commerce – and integrating them to find an optimal solution. We bring a highly effective problem-solving approach to the challenges that come our way. Those who wish to make a difference to the world should, I suggest, become engineers'.*[202]
2007	UK Higher Education Academy (HEA)	*'Amongst the greatest challenges we face in the world today are those of delivering growing, secure and affordable supplies of clean water and of energy, to meet the needs and expectations of an expanding population, whilst reducing our CO_2 emissions and the human contribution to climate change. The implementation of innovative engineering solutions is fundamental to addressing these challenges, whilst also offering exceptional opportunities for economic growth to the nations which are able to deliver them."*[203]
2008	Engineers Australia	*'The concept of sustainability will influence almost all engineering developments and the potential effects on the environment, long term and short term, proximate and remote, will be integrated routinely into engineering design and planning'.*[204]
2009	WFEO/ The Institution of Engineers Australia	*'In light of the wealth of information available to the engineering profession, there is significant impetus to review what we do and how we do it. However, our references to Sustainable Development are for the most part still at too high a level. There must be a greater degree of detail provided by educators so that students have to think very carefully about the issues at hand. It is sobering for our profession to realise that this is not yet the norm for most of our engineers in training'.*[205]
2008	Chinese Academy of	*'If China continues with a traditional development pattern, its resources will not be sufficient to support its growth, and the*

Year	Organisation	Statement
	Engineering	*environment will be unable to bear the added burden, which will make it extremely difficult for China to realize its goal of becoming a prosperous society … Faced with the dilemma that it cannot undertake a traditional industrialization program like those adopted earlier by developed countries at a cost of huge energy consumption and severe environmental pollution, nor can it immediately become a post-industrialization society, China must develop new methodologies and approaches to industrialization that are characterized by high technological content, desirable economic effects, low resource consumption, little environmental pollution, and effective human resources.'*[206]

Source: References noted within the table.

- ***Shifting requirements for practising engineers by professional organisations:***

  While some accrediting organisations have not yet adopted specific requirements of their practising engineers for sustainability, a number of high profile overarching professional organisations have been strengthening their policy statements and operating principles for members, in line with sustainable development. Table 1-10 summarises key professional documents outlining the changing role of the engineering profession. Many engineering organisations are members of at least one of these 'umbrella organisations'.

  A review of the codes of ethics and operating principles for professional bodies listed in Table 1-9 also shows that all have some kind of sustainability requirement for their members. For example, the Australian Engineering Code of Ethics statement contains a direct imperative, stating in Tenet 6 that,

  > *'Members shall, where relevant, take reasonable steps to inform themselves, their clients and employers, of the social, environmental, economic and other possible consequences which may arise from their actions'.*[207]

  The Chinese Academy of Engineering (CAE) is now also conducting a national study on '*fostering innovative engineering talent'*, which includes a focus on reforming engineering educational curriculums in universities, enhancing engineering field training and case studies and developing student competence in solving practical engineering problems, while advocating an innovative spirit and entrepreneurship.[208] It is likely that, together with emerging national legislation and policies on sustainable development practices, this process will strengthen education for sustainable development nationally. Given that the vast majority of engineering graduates each year are in China (see Table 1-11), this also has potential international implications.

Table 1-10. Examples of strengthening professional requirements for EESD

Date	Key Documents Outlining Professional Requirement
1990	FIDIC introduced environmental policies including guidelines on the obligations of the consulting engineer with respect to their projects and clients.[209] FIDIC, the United Nations Environment Program (UNEP), and the International Chamber of Commerce (ICC) developed training programs for their members and for industry to provide guidance on how to describe and analyse environmental issues as well as setting up environmental management systems.[210]
1992 – 1996	World Engineering Partnership for Sustainable Development - WFEO, FIDIC and the UATI - formed a collaboration to lay the groundwork for the many programs in support of sustainable development that are being pursued by WFEO, FIDIC and other international organisations through their members and committees.
1997	Joint paper entitled 'Role and Contributions of the Scientific and Technological Community to Sustainable Development', produced by the International Council for Science (ICSU), WFEO, Third World Academy of Sciences (TWAS), the InterAcademy Panel (IAP), and the International Social Science Council (ISSC),[211] following the 1996 World Congress of Engineering Educators and Industry Leaders, organized by UNESCO, UNIDO, WFEO and UATI which devoted considerable attention to education and sustainable development concerns. The World Federation of Engineering Organisations also produced 'The Engineer's Response to Sustainable Development'.[212]
2001	WFEO Model Code of Ethics, which states that, *'Engineers whose recommendations are overruled or ignored on issues of safety, health, welfare, or sustainable development shall inform their contractor or employer of the possible consequences'*.[213]
2006	International Federation of Engineering Education Societies (IFEES) - a network of 35 engineering organisations including WFEO and FIDIC - formed to establish effective engineering education processes of high quality around the world, to assure a global supply of well-prepared engineering graduates. According to Founder and President Professor Claudio Borri, '*In a few words, the key-question posed by the 21st century global economy to engineering educators and stake-holders is this: How can education in science and technology help to reduce poverty, boost socio-economic development, and take the right decisions for sustainable and environmental compatible development?'.*[214]

Source: References noted within the table.

- ***Shifting accreditation requirements for graduate engineers:***

  In engineering education, external agencies appear to be the primary reason for curriculum renewal, with regular reference in the literature to meeting changing accreditation requirements.[215,216] Examples of major accreditation triggers in the past include the American Accreditation Board for Engineering and Technology (ABET) SUCCEED ('Southeastern University and College Coalition for Engineering EDucation') initiative during the 1990s,[217,218,219] SARTOR 97 ('Standards and Routes Towards Registration') in the United Kingdom,[220] and the European EUR-ACE ('EURopean Accredited Engineer') initiative (2004-2006).[221]

Many engineering job descriptions require that engineering employees have graduated from accredited undergraduate degree programs, and requirements for registration to practice engineering, professional indemnity and personal liability certification for practicing favour successful completion of an accredited engineering degree program. Internationally, engineering qualifications may be recognised in different countries, based on international agreements and accords. In addition, the professional engineering career path includes the opportunity for graduates to gain chartered status certification, where certification provides a measure of quality assurance that graduates will have attained base 'competencies' or 'attributes'.

Over the last 20 years, many institutions responsible for accrediting engineering degrees and co-ordinating agreements have strengthened their position on EESD through more rigorous accreditation requirements that deal with the environment and sustainable development. A number of engineering accreditation authorities have updated their competency requirements to address emerging 21st Century challenges, including incorporating criteria for sustainability knowledge and skills. The three major engineering international accords (i.e. the Washington, Sydney and Dublin accords) now require that programs develop graduates who, '*understand the impact of engineering solutions in a societal context and demonstrate knowledge of and need for sustainable development*'.[222]

As can be seen from Table 1-11 the most explicit sustainability accreditation requirements, such as those in the United Kingdom and Australia, affect a relatively small proportion of global engineering graduates. However, the International Engineering Alliance (IEA) has a potentially large influence on national accreditation requirements in a number of countries through its co-ordination of qualification recognition internationally. The IEA currently has three key agreements covering mutual recognition related to tertiary-level qualifications in engineering, known as the 1989 *Washington Accord* for professional engineering, the 2001 *Sydney Accord* for engineering technology, and the 2002 *Dublin Accord* for technician engineering.[223] These three accords have now moved to one set of rules, procedures and performance guidelines, representing expectations for membership.[224] In the guidelines (not yet mandatory) there are 13 aspects of the 'graduate profile exemplar' which contain many references to aspects of sustainability such as systems design, 'the engineer and society', ethics, and 'environment and sustainability'. Specifically the exemplars state that graduates should,

> *'understand the impact of engineering solutions in a societal context and demonstrate knowledge of, and need for, sustainable development'.*[225]

Signatories of the *Washington Accord* include Australia, Canada, Chinese Taipei, Hong Kong, Ireland, Japan, Korea, New Zealand, Singapore, South Africa, UK and the US. The Accord also acknowledges provisional members who are given two years to ensure their academic systems are at an international level, to then be considered for full membership.[226] These countries currently include Germany, India, Malaysia, Russia and Sri Lanka. A notable absence from the Washington Accord at this stage is China. If the IEA chooses to make the guidelines a mandatory attachment to the regulations, then sustainability knowledge and skill requirements will be increased for many accreditation bodies internationally.

However, the explicit nature of requirements in accreditation documents is still highly variable, where some are very loosely worded which enable engineering departments to effectively 'tick the accreditation box' with minimal or no sustainability content. Furthermore, these accreditation revisions often still include sustainable development together with health and safety requirements in engineering education, rather than being considered with regard to its complexity and interdisciplinarity.

This is problematic considering how little health and safety is covered in the standard engineering curriculum (i.e. a few introductory lectures).[227] Heywood reflects that the international demand for accountability has meant that quality assurance has been a major driver for curriculum renewal at all levels of the institution. However, while engineering is not exempt from these conditions, it has, like all professional subjects, its professional requirements to meet. In institutional debates about funding it will use those requirements to try and protect its resources.[228]

Using accreditation requirements to gauge the extent of EESD is also problematic as the process of embedding new knowledge and skills into the curriculum is much longer than the initial politicising of its inclusion. When the accreditation requirements change, the institutions may require the new knowledge and capabilities to be included within one or more accreditation rounds (each of five years or more). Hence, there may be a considerable lag between the institutional accreditation requirements and actual curriculum renewal. Table 1-11 provides examples of engineering accreditation institutions in a number of countries around the world and their requirements for graduate competencies within the field of sustainability.

Table 1-11. Example accreditation requirements in sustainability competencies

Country	Shifting Accreditation Requirements
China	China is the largest producer of engineering graduates in the world, with 600,000 college and university engineering graduates in 2005.[229] While China's engineering accreditation system is still being formalised, HEIs in China have been proactive in sustainability initiatives,[230] including hosting forums such as the 2006 UNESCO Workshop on Engineering Education for Sustainable Development (Beijing) at Tsinghua University, supported by the China Association for Science and Technology, the Chinese Academy of Engineering and the World Federation of Engineering Organizations. This workshop identified and emphasised the need for, *'learning and teaching materials, methods and capacity in EESD, and for better incentives for engineers to work, research and publish in the field of engineering and SD (ESD, e.g. accreditation, work opportunities, research grants, peer-reviewed publications)'.*[231]
India	India graduates between 350,000 - 500,000 engineers each year, depending on what is used to define graduation requirements.[232] In 2007, India's National Board of Accreditation was inducted into the Washington Accord, which requires the country's accreditation system to quickly align with the Accord's requirements, which includes some sustainability competencies.
United States of America	America produces approximately 70,000 engineering graduates each year. The American Accreditation Board for Engineering and Technology (ABET) state in their engineering accreditation criteria that engineering programs must demonstrate that their students attain, among other things, *'an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability'.*[233]
United Kingdom	The United Kingdom (UK) graduates approximately 12,000 engineers each year, from the pool of approximately 100,000 European engineering graduates. The Engineering Council is responsible for the UK register of Chartered Engineers, Incorporated Engineers and Engineering Technicians. The importance of sustainable development is clearly identified in the Council's *Standard for Professional Engineering Competence* (UK-SPEC) which came into force in 2004. It includes a statement that Chartered Engineers must, '*undertake engineering activities in a way which contributes to sustainable development*'.[234]
Australia[235]	Australia produces approximately 6,000 graduates each year. In 2006, the Institution of Engineers Australia (EA), the industry body which accredits engineering education, revised the accreditation criteria, system, and processes for professional engineering qualifications, focusing on industry liaison and broad graduate attributes, encouraging engineering schools to devise innovative curriculum and pedagogy to meet 'alternative missions'.[236] EA has incorporated specific competencies related to sustainable development into the associated *Australian Engineering Competency Standards – Stage 1 Competency Standards for Professional Engineers*,[237] including statements such as, '*professional engineers are required to take responsibility for engineering projects and programs in the most far reaching sense… including understanding the requirements of clients and of society as a whole; working to optimise social, environmental and economic outcomes over the lifetime of the product or program*'.

Source: References noted within the table.

- ***Increasing commitment and action to EESD by highly regarded university peers:***

  At an institutional level, universities are becoming increasingly vocal about their commitment and achievements with regard to education for sustainable development. Further to key university alliances for ESD summarised in Table 1-2, three international university alliances focusing specifically on EESD are summarised in Table 1-12.

Table 1-12. Examples of international university alliances promoting EESD

Alliance	Brief Description
Alliance for Global Sustainability (AGS)	A university alliance including the Massachusetts Institute of Technology (MIT) the Swiss Federal Institute of Technology-Zurich, the University of Tokyo and Chalmers University of Technology in Sweden.
Going Global Forum	A forum initiated by MIT, to facilitate international working sessions on sustainability in higher education (by invitation).
CDIO Network	The Massachusetts Institute of Technology (MIT) has developed an approach to engineering education that integrates a number of skills with disciplinary knowledge, within the context of engineering practice i.e. 'Conceiving, Designing, Implementing and Operating' or 'CDIO'.[238] There are now more than 100 collaborating universities internationally who are in the process of introducing the 17 CDIO principles into their engineering programs, including sustainability.[239]

Source: References noted within the table.

1.3.4 Drivers limiting EESD in market/ business

- ***Persistent 'old economy' industry practices:***

  Hargroves and Smith[240] note old-economy industry practices as a possible reason for a lack of business and industry action, where the relatively small number of current employers calling for graduates who are literate in sustainability are perceived to be foregoing the 'opportunity' to continue with unsustainable practices as long as they can before being required to stop. Meanwhile, other companies may still choose to invest in carbon intensive technologies while they can, continuing to put a demand on engineering skill-sets that do not contribute to sustainable development. Given the lack of government direction identified above, there is still often the opportunity to do little and continue to meet regulatory requirements to reduce pollution and emissions that have low expectations and long timeframes for conformance. Higher education institutions may continue to perceive such a market signal for graduates with conventional knowledge and skills as a continuation of the 'norm' rather than an effort to improve profit in the short term before reforms are put into place that call for systemic changes.

- ***Perceived threat to employability and position:***

  As noted in the WFEO publication on issues and challenges for the engineering profession in the 21st Century,[241] a change in perspective of what constitutes 'engineering practice' may also pose a potential perceived threat to employability and require investment with regard to retraining existing staff. This may fuel employer and employee resistance to change, and subsequently demand for graduates with these new skills and knowledge. Within the academic context, faculty members may similarly anticipate that their knowledge may become redundant or superseded within a renewed EESD curriculum. They may also anticipate implications for their position if they admit that curriculum renewal is needed and is perhaps overdue. For this set of practising engineers and managers within HEIs, progress in EESD may ultimately rely on the gradual replacement of the current generation of engineering professionals with a new generation with different beliefs and convictions.

- ***Short-termism in the higher education institution (HEI) sector:***

  It is widely recognised that one of the biggest barriers to corporate sustainability is short-term pressures from the market for ever increasing quarterly profit results, as evidenced in a 2004 report by the World Business Council on Sustainable Development, which discusses why corporations have been slow to change to sustainable practices.[242] For example, the Business Council of Australia (BCA) has argued that stock market driven short-termism is threatening the long-term competitiveness of firms, where increasing demand from shareholders for greater quarterly profits is preventing CEOs from making the investments companies need to position themselves for higher profitability in the medium to longer term, stating that a timescale is also needed for commitment to Corporate Social Responsibility and wider sustainability imperatives.[243] While corporations aim to meet short term stakeholder expectations for growth and increasing profit margins in quarterly and annual reports, engineering deans are also faced with half-yearly student enrolment reporting, annual budgets and short appointment terms of 2 - 3 years. Deans may be keen to 'make their mark' on the school and the program, with lower priority on longer term transitions past the next program accreditation cycle. It may also be difficult to obtain major budget allocations for program revisions, and regular restructures within the academic bureaucracy may take time and resources away from curriculum renewal.

- ***A shortage of engineering graduates:***

  The current shortage of engineering graduates around the world[244] is increasingly resulting in a 'take what you can get' scenario, where employers are prepared to

train graduates in-house, or outsource professional development through specialised institutions. When large organisations continue to recruit graduates with little or no capabilities in this area and then train them with the required sustainability knowledge and skills sets, they inadvertently send a market signal to engineering education institutions that they are satisfied with the product. This results in a scenario where employers are paying an additional cost to train their graduates in base competencies that should 'come with the product'. In addition, the higher education system's perception of the need for conventional graduates is reinforced. Again, universities that move early to integrate EESD can potentially offer a more rounded product as the demand increases.

1.3.5 Drivers limiting EESD in information/ technology

- ***Growing disconnect between engineering and science:***

  While engineers who are active in public bodies may vocalise the need for change, they perhaps do not represent the engineer in the average work environment. In this less-public view, engineering professionals are not aware of the complexity and interdisciplinary nature of the 21st Century challenges that their science colleagues are describing. Across academia and in practice, engineers have a pervading belief in established technology as the solution, seeing sustainability as a threat which brings into question many current practices. For these engineers, rather than being challenged by the professional practice implications of the issues raised by the scientific community, sustainable development is 'an additional thing to consider' when teaching or doing research and therefore ignored unless it is clearly required, or used as a marketing term to win more project work and fund more research. As EESD researcher Professor Karel Mulder from Delft University reflects,

  > *'Anecdotal evidence of low enrolments in new interdisciplinary programs (such as Industrial Ecology) supports the argument that EESD should leave the core of engineering unaffected, instead adding an extra sustainable development course on occasion, as current engineering is supposedly already well equipped to address 21st Century challenges'.*[245]

  Thus, it appears that while high profile engineers in public life may be advocating the need for change, parts of the engineering community – from engineering design offices, to factory floors and education institutions around the world – are still arguing that there is no need for a substantial change in their skill-set, despite the leading edge scientific findings that call many current practices into question.

- ***Lack of convenient access to emerging and rigorously reviewed information:***

  While the emergence of the internet has dramatically improved access to content over the last decade, the literature notes that many countries, particularly developing countries, still have limited and slow access to this information resource. There exist example initiatives such as the Sudanese Virtual Engineering Library (SudVEL),[246] where significant literature resources are made available through a local server on campus. However, these have not been replicated in other developing countries. For those academics who do have good access to the internet, renewing curriculum can still be a bewildering experience with literally thousands of websites on topics such as sustainable development technologies, energy efficiency, and climate change. Currently there are few EESD resources recommended by professional bodies or associations, which academics could confidently access. A notable exception is the materials developed by The Natural Edge Project, highlighted in the Australian report on 'Addressing the Supply and Quality of Engineering Graduates for the New Century' as an example of best practice in this area.[247]

- ***Lack of access to information in foreign languages:***

  In addition to the issues associated with internet availability, the lack of content in the first language of the institution is another potential reason discussed in the literature, which could contribute to a lack of curriculum renewal activities in eastern, Asian and sub-Saharan countries. Conversely where countries that don't speak English might be succeeding in curriculum renewal activities, their strategies and learnings may not be translated for sharing with colleagues in other countries. While organisations such as Japan for Sustainability (JFS) work to translate initiatives between English and other languages, there is still a possible language disconnect that could be inhibiting the integration of sustainability content into engineering education.

1.3.6 Drivers limiting EESD in institutions/ civil society

- ***Lack of strong requirements for change:***

  Business now clearly understands that swift action to address challenges such as climate change and sustainable development will be required sooner or later, but a lack of certainty on government legislative responses makes it difficult to be strategic. The signals from industry for graduates who can address these requirements are therefore not strong. Current demand for engineers with sustainability skills and knowledge is happening despite the relative absence of strong government signals. This is described in the *Stern Review* as 'policy-induced uncertainty',[248] an example of which is penalising environmental 'bads' such as

carbon dioxide emissions and waste generation. Such uncertainty may inhibit investment in sustainable development, which in turn may inhibit the mainstreaming of demand for engineers with these capabilities. Once there is clear direction on greenhouse gas emission requirements, for example, then perhaps this will increase industry demand for the engineering skill-sets necessary to address the problem, sending a signal to higher education institutions to update what their engineering students are learning.

- ***Lack of academic staff competencies in EESD:***

  There is a growing set of literature on the issue of lack of capability in EESD among academics.[249,250] Generally speaking, engineering educators teach according to their education and experience, with a relatively low rate of professional development among faculty members. Where sustainability has not formed part of their training, faculty are unlikely to consider it as a skill of value. Indeed, some academics argue that students should be given the fundamentals which remain constant over time, and which can be applied to whatever problems arise. In this argument, these 'fundamentals' should not be diluted to include passing 'fads'. Organisations such as the American Association for the Advancement of Sustainability in Higher Education (AASHE) dedicate a web page to highlighting such opportunities for academic staff.[251]

1.3.7 Conclusion

In conclusion, within the professions, there is a key role for engineering in addressing 21st Century challenges and a clear high-level commitment to engineering education for sustainable development internationally, across government, industry and academia. However, the literature suggests an *ad hoc* and highly variable approach to such curriculum renewal and it is concluded that there has not been a large-scale transition to producing engineering graduates with the knowledge and skills to meet the changing needs of the profession over the coming 1-2 decades in particular. Moreover, while engineering education has undergone periods of curriculum renewal to embed professionalism, ethics, and health and safety, the profession has not had to make a significant shift in the way it fundamentally teaches students across all disciplines since the first engineering professionals emerged following the Industrial Revolution.[252] There exist a number of significant drivers promoting curriculum renewal within engineering education. However, such calls are being tempered by a number of drivers that are limiting the progress of curriculum renewal.

Considering the literature on the state of engineering education for sustainable development, these barriers appear to have been strong enough to-date, to prevent a transition towards engineering education for sustainable development (i.e. time 't' in Figure 1-2) in the majority of universities around the world. Hence, despite high level commitment to EESD, in the period 'pre-t' where there is an absence of a strong requirement for improvement in the area, coupled with limited resources, an increasingly competitive education market, and pressures to accommodate research and teaching requirements, many engineering departments around the world are doing little more than including one or two 'sustainability' courses within existing programs, leaving isolated individuals or small teams within departments to undertake *ad hoc* curriculum renewal efforts. In reality, most current engineering degrees are still focused on the outdated 'old economy', 'fossil-fuel' engineering approaches[253] involving linear 'heat, beat and treat' processes that don't tend to consider rethinking waste or other externalities as part of the process.

1.4 An emerging time lag dilemma for EESD

Considering the sustainability literature discussed at the beginning of this chapter, together with EESD literature discussed in the previous section, it is apparent that there is an emerging time related imperative facing the engineering community. As an invited expert on the topic of sustainable development, Jonathan Porritt stated at the 2007 Global Sustainability Forum on the future for engineering education (Imperial College, London), practices need to have changed substantially by around 2020 – 2025:

> *"The 'business as usual' model, where profits come before sustainability, is absolutely finished. We now have a window of ten to 15 years to adopt a sustainable approach before we reach a global 'tipping point'- the point at which mankind loses the ability to command growth and development".*[254]

The majority of students beginning their undergraduate studies in 2010 will be moving into decision-making positions in 10-15 years time (i.e around 2025) when society is likely to need significant assistance in dealing with 'tailing' issues such as sustaining long term reductions in greenhouse gas emissions, and dealing with the effects of climate change. Despite an absence of discussion in the literature, anecdotal evidence from discussions with engineering educators[255] suggests that a typical (or 'standard') process of undergraduate curriculum renewal may take 3-4 accreditation cycles (of approximately 5-year intervals) to fully integrate a substantial new set of knowledge and skills within all year levels of an engineering degree; i.e. between 15-20 years. Given that the average pathway to graduate from a built environment program (for example in design, engineering or planning) is approximately 3-5 years, from enrolment to graduation, followed by 3-5 years of on-the-job graduate development, if HEIs take the typical approach over a 15-20 year period to fully renew such bachelor programs, this will result in a time lag of around 21-29 years; 2-3 decades before students graduating from fully integrated programs will be in decision-making positions. Clearly this is well beyond the timeframes needed to address the peaking or tailing challenges described earlier in this chapter.

For postgraduate students the time lag will be shorter as students may already be practising in their field and studies are shorter over 1-2 years. However the time lag may still be in the order of 5-10 years depending on the curriculum renewal process, which still potentially results in a lack of capacity in the professional sector over the next decade when action is needed to address urgent climate change and sustainable development issues, for example 'peaking' pollution such as greenhouse gas emissions.

Along with understanding that current education systems are poorly prepared to rapidly develop knowledge and skills related to reducing environmental pressures, it is important to understand that it is logistically impossible for the education system to change 'overnight', as programs need to balance the current student demands and expectations with industry expectations for graduate attributes. Figure 1-4 shows how the transition might occur, with a period of rapid curriculum renewal followed by continual program improvement which follows a regular improvement cycle of research, curriculum development, trial, evaluation and review. Over repeated cycles, the new knowledge and skills are gradually integrated into the curriculum.

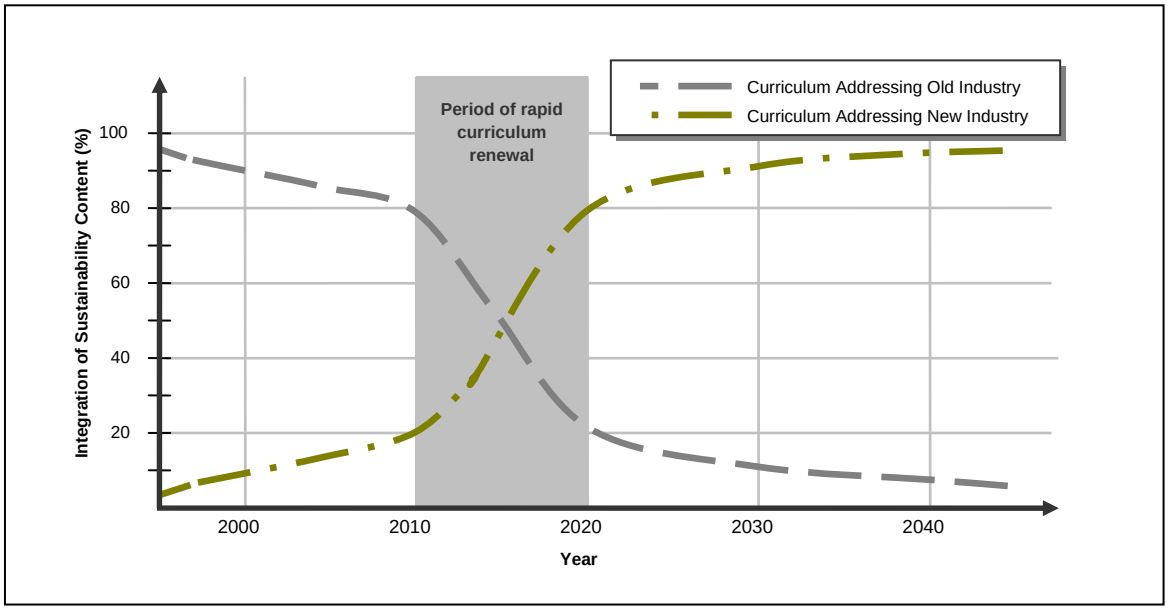

Figure 1-4. An illustrative curriculum transition curve, showing a period of rapid curriculum renewal within a larger process of continuous curriculum renewal

For EESD the figure also demonstrates the need to time the transition from 'old industry' to 'new industry' education matching changing curriculum with demand for such graduate attributes by employers. As part of the transition towards more sustainable infrastructure, society's 'old industry' plant and equipment will still require service and maintenance by professionals with 'old industry' knowledge and skills. However the balance of 'old' and 'new' needs to be carefully managed in relation to the emerging needs of society and employer demands. As there is a large amount of embedded infrastructure (for example roads, bridges, power stations, electricity grids etc) to be managed, maintained and transitioned, requiring 'old industry' education, integrating 'new industry' content too quickly could be problematic if graduates don't have the skills that the employment market needs at the time that they graduate.

With this perspective, it is evident from the literature that curriculum renewal considerations are complex. Moreover, within the current processes for curriculum

renewal, the timeframe for updating undergraduate engineering curriculum using standard methods may be too long to ensure that engineering professionals will be equipped with knowledge and skills that can address short and longer term challenges while still being able to maintain current systems. The extent of the 'time lag' will depend on how quickly the new knowledge and skills are embedded into engineering curriculum, to the point where a student can begin studies in first year, and fully develop the new set of desired knowledge and skills (or 'graduate attributes') by the time they graduate. As schematically illustrated in Figure 1-5, this may not have been the situation had HEIs acted on the major previous calls for capacity building related to sustainable development, such as in *Our Common Future* in 1987.

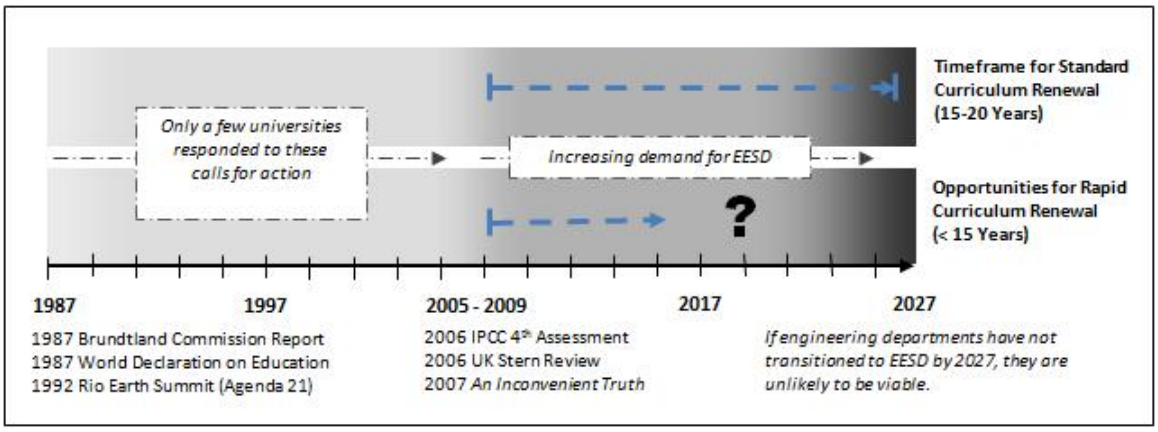

Figure 1-5. A diagrammatic representation of the time lag dilemma, showing timing issues

Source: Desha and Hargroves (2007,[256] 2009[257])

Along the x-axis timeline, major calls for change within the higher education system for ESD are noted, starting approximately 20 years ago. Following these calls, between 1987 and 2005 a relatively small number of engineering education institutions undertook a process of curriculum renewal to EESD in some form, primarily within undergraduate programs.[258,259] Such efforts over this period included the Georgia Institute of Technology program at the Centre for Sustainable Technology in America, which in the mid 1990s sought to develop a curriculum on sustainable development and technology,[260] in addition to efforts by leaders such as Delft University, Chalmers University and Monterrey University (see Chapter 3). In 2005-2007, there were a number of significant additional calls for action from the scientific, economic, political and media communities (as highlighted earlier in this chapter), which brought sustainability issues to the forefront of the global consciousness. These recent calls for action provided an imperative to act within the next two decades, to avoid significant ecosystem failure.

This observed 'time lag dilemma' facing engineering education has significant implications for society if the process of curriculum renewal for EESD is not addressed.

Furthermore, there are implications for engineering departments as they make decisions about the scale and pace of curriculum renewal for EESD as regulations and the market continue to change, in addition to increasing accreditation requirements. Engineering department may also be exposed to potential risks with regard to both student demand for the program/s, and tightening accreditation requirements for the program/s. However, departments need to be wary of keeping pace with graduate demand (i.e. not stepping too far in front) to ensure that their graduates remain employable and in demand throughout the process.

Drawing on the literature, Figure 1-6 presents an illustrative representation of the relationship between a department's commitment to EESD and potential risk and reward implications. Risks include for example falling student numbers, increasing accreditation difficulties, poaching of key staff.

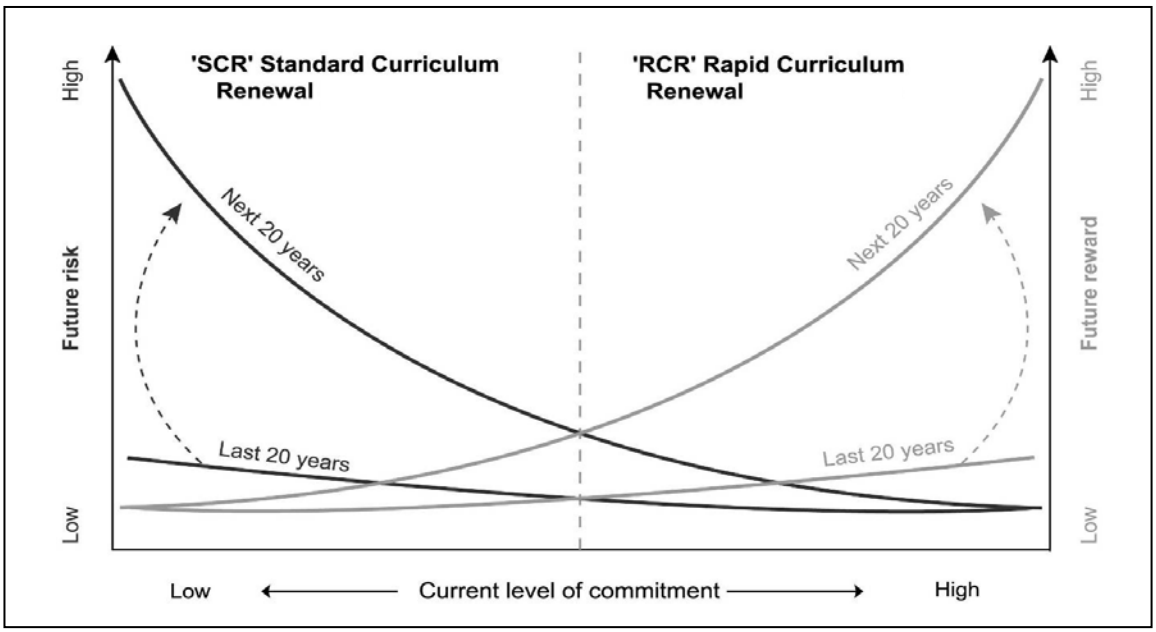

Figure 1-6. Risk and reward scenarios for curriculum renewal in higher education

Source: Desha *et al* (2009)[261]

Rewards include for example attracting the best students and staff, staying ahead of accreditation requirements, attracting research funding, securing key academic appointments and industry funding. For the last 20 years, there has been relatively low risks and benefits from seeking to accelerate curriculum renewal, evidenced by the relative lack of action in curriculum renewal. However, recent market, regulatory and institutional shifts around environmental and sustainable development related issues, together with the significant shift in public opinion on these matters, and the increasing competition among HEIs, have caused the level of both the risks and the benefits to increase dramatically. This situation presents significant cause for universities and

engineering departments to rethink their strategies related to curriculum reform in order to minimise the risks and capture the rewards.

To complicate matters further, this risk-reward relationship changes over time, for example:

– The risk curve may be affected by a range of potential events and shifts in the market and society that would cause it to lift up (vertically) along the y-axis and increase the risk throughout the schematic. If a carbon trading scheme is initiated, for example, then the large companies that currently produce high levels of emissions will likely require related competencies in their recruitment strategies. If the cost of petrol rises significantly, then society will require rapid innovation across all sectors to address the manufacture and supply of goods and services. Mechanical and electrical engineers will be expected to design more efficient processes, equipment and vehicles, and civil engineers will be expected to design more efficient transport systems and infrastructure. In the face of such rapid shifts, departments that are unprepared could face increasing accreditation difficulties, falling student numbers, with the potential for staff loss and restricted research opportunities. In addition, their graduates will be less employable. Such reduced performance may also call for drastic measures, such as restructuring, as a result of the struggle to deal with accreditation, students and staff retention.

– The benefits curve may be affected as departments transition to EESD and as the supply of graduates with sustainability knowledge and skills subsequently catches up with demand. This changing competitive environment could mean that a department's efforts in curriculum renewal will just be keeping up with the market, rather than leading with something new and innovative. While including EESD may provide benefit to the department at this time (i.e. with recruitment etc) it may not be as significant as if the department had undertaken the change when fewer competitors were offering similar programs. Hence, the benefit curve may flatten over time.

In short, over the coming years as the risk curve rises and the benefits curve flattens, departments who do not transition their programs to EESD are likely to find an increasingly difficult operating environment. Hence, in a world where there are such time-bound imperatives for change, it is considered pertinent to investigate how engineers can more rapidly progress to be able to address the challenges facing society today. The literature suggests that a focus on education is key to achieving this goal. Moreover, the time lag dilemma facing engineering educators with regard to undergraduate curriculum – and to a lesser extent postgraduate curriculum – requires a

reconsideration of curriculum renewal processes, as demand for graduates equipped with sustainability related knowledge and skills begins to put pressure on standard methods. With this understanding, contextually sensitive processes for rapidly renewing the curriculum – i.e. undertaking 'rapid curriculum renewal' – to embed sustainable development within engineering are worth extensive exploration, with future potential application to a variety of other disciplines facing similar urgent and challenging circumstances.

Given the timeframes discussed earlier, engineering departments undertaking a process of rapid curriculum renewal toward EESD ideally need to complete the transition for undergraduate programs within 6-8 years (i.e. within 2 accreditation cycles), to produce graduates who can play key decision making roles in addressing longer term challenges in 10-15 years time. Indeed, the literature suggests that such a timeframe reduces the potential risk of not keeping up with market, regulatory and institutional shifts. Furthermore, a transition to postgraduate engineering education for sustainable development also needs to be completed as soon as possible to help equip practitioners and decision-makers with knowledge and skills to address immediate issues such as peaking greenhouse gas emissions and decoupling economic growth from reliance on fossil fuels.

1.5 Rationale for the research

In this section the findings from the literature review are used to discuss the impetus for the research, and the assumptions used to set the research question. As demonstrated in the literature review, EESD is both urgent and necessary, and yet there still has not been a significant shift in the curriculum of most engineering education institutions. In addition, the timeframe for engineering educators to equip professionals with new skills related to environmental management and sustainable development is converging with the timeframe for the engineering community to successfully assist in addressing short and longer term sustainability challenges, resulting in a time lag dilemma facing engineering education.

In light of these findings, the research question is about issues, processes and resolutions that occur when curriculum renewal is sought in urgent or changing and challenging times. The focus is on mechanisms for 'curriculum renewal in a time of urgency', where the case example being considered is engineering education for sustainable development, given that this scenario is clearly demonstrated in the issue of embedding sustainability into engineering education. Ultimately, if the study uncovers new considerations for curriculum renewal in changing and difficult circumstances, the aim is that this could be studied further and the theoretical framework applied in other disciplines experiencing similar imperatives for rapid curriculum renewal.

Within this context, the overarching research question was subsequently refined over the course of the thesis development to the following:

> *'How can embedding sustainability knowledge and skills within engineering programs be effectively undertaken, in the context of rapid curriculum renewal in urgent and challenging times?'*

With regard to terminology used in the research question, a number of terms are used intentionally. 'Rapid' is used with regard to the context of the situation as a comparative term,[262] evidenced in terms such as rapid acceleration of a vehicle from standstill, rapid ingestion of a drug, and rapid diffusion of a new piece of technology within society. This study is focused on achieving rapid integration of new knowledge and skills in a process of program-wide curriculum renewal – i.e. rapid curriculum renewal – in the higher education sector within a decade (i.e. within 2 accreditation cycles), compared with laissez-faire curriculum renewal which may take anywhere up to 15-20 years. In exploring the notion of rapid curriculum renewal, this study is focused on how it may occur in particular circumstances, namely when there is widespread expectation for 'urgent' (i.e. immediate)[263] attention and action, for example by professional

organisations, government, and industry. Mechanisms for creating this expectation is not the focus of this study, but is briefly discussed in Chapter 6. This study is also focused on times when new knowledge and skills are needed to address 'challenging' (i.e. complex and complicated) [264] issues requiring much skill or effort, assuming that this will lead to the need for program-wide curriculum renewal (as opposed to the amendment of one or two courses).

This research question contains a number of assumptions which have been validated through the literature review:

– Sustainable development is the preferred end-goal for society globally.
– Delivering sustainable development requires some level of contribution by engineers.
– Knowledge and skills about sustainable development need to be developed during undergraduate years.
– Engineering programs may already include some sustainability knowledge and skills, but across the engineering education sector this knowledge and skill set needs improving.
– The process of 'embedding' sustainability into curriculum will improve this knowledge and skill set.
– Accelerating this process will lead to engineering graduates who are better equipped to address these global environmental challenges.

Two key aspects of the research problem are what curriculum renewal comprises, and whether curriculum renewal in a time of critical urgency is a different curriculum development process from renewal in 'ordinary' circumstances – i.e. during times of laisser-faire education, which comprised incremental curriculum development process over time. In particular, what does the literature say about such 'evolutionary' curriculum renewal, in contrast to 'revolutionary' curriculum renewal. Does curriculum renewal in a time of urgency depend on certain factors, or 'elements'?

The dissertation is hence about understanding and adding to conceptual knowledge associated with curriculum renewal and 'rapid curriculum renewal'. Within this research, a sufficiently concrete understanding of what constitutes rapid curriculum renewal will be developed, in particular, the elements that are part and parcel of the processes that accompany such a rapid curriculum renewal process within a university environment. In the final chapter, this understanding will be built upon to consider the implications for education institutions, professional organisations and educators, in implementing rapid curriculum renewal, and implications for further research in the field.

The proposed disciplinary field for this thesis is in Curriculum Theory, as a subset of Educational Theory. Specifically, the study sits within the theoretical area of Curriculum Renewal in Higher Education, which asks how the process of embedding (or integrating broadly and deeply) new concepts and content into existing higher education curriculum can be accelerated, to achieve a rapid shift in expected student learning outcomes to meet a revised set of requirements.

Drawing on the strong links between higher education and its ability to shape society, this study uses the theoretical framework of Curriculum Renewal in Higher Education in the professional discipline of engineering education. It examines how the process of embedding sustainability as an emerging concept and with defined content and new design performance criteria, can be accelerated within existing engineering curriculum anywhere in the world, to rapidly shift or 'transition' the knowledge and skill-set of graduating engineers to be able to contribute to sustainable development (i.e. 'engineering education for sustainable development'). This study uses a new term to describe this area of theory, called 'rapid curriculum renewal'. Hence, the thesis could be summarised as 'facilitating curriculum renewal in engineering education through developing a model for rapidly transitioning to education for sustainable development'.

This research question is considered significant for the following reasons:

1. The exploration of this issue of 'curriculum renewal in urgent and challenging times' is particularly timely, as is evident from the literature that higher education sector is unlikely to enjoy the luxury of laisser-faire curriculum renewal in the future. The education sector has reached a point where issues worldwide are starting to press on the curriculum renewal process, demanding a more rapid response from the education sector. Therefore, it is opportune that the study is highlighting that the sector can no longer take time for granted.
2. This research question is important to contributing to the emerging understanding that leadership in engineering education is not about continuing to teach current engineering content, by bringing together literature on the state of engineering education and demonstrating a growing understanding of 21st Century engineering.
3. This research question explores mechanisms to accelerate the embedding of education for sustainable development within engineering curriculum. The engineering profession has the potential - if suitably equipped - to be a major contributor to a societal transition to sustainable development. There is currently a global need across business, government and the community, for engineers and designers who are educated in the various options for delivering sustainable

solutions to society's challenges. Through providing guidance on processes of rapid curriculum renewal for sustainable development, universities around the world will also have a strong foundation to consider engaging with the process.

4. This research question provides an opportunity to learn from curriculum renewal successes within engineering and also from other discipline areas. It is apparent from the literature, that engineering higher education needs to embed issues associated with sustainable development for engineers broadly and deeply, if it is really going to effect any changes in engineering outcomes in the future. In the context of environmental challenges, constrained university budgets, and limited teaching resources, it is critical that any changes to education are made with as much consideration and learning from prior experiences as possible.

5. The research question provides an opportunity to develop a number of core elements of curriculum renewal into a framework to make a contribution to curriculum renewal theory in higher education. There is currently a lack of reference material for managers and heads of schools/engineering departments who are looking to transition the curriculum towards engineering education for sustainable development. Experiences of educators involved in mainstreaming environmental management across engineering programs offer significant insight into a range of elements that may be suitable for a broader curriculum renewal. The study focuses on developing a number of core elements to be brought together in a framework that provides guidance on the breadth and depth of the process of integrating sustainability within engineering education.

6. The research question provides a platform for future research, based on the outcomes of this study. The speed to which a transition to engineering education for sustainable development can occur will likely be impeded to a certain extent by the nature of institutional practices. However, the conceptual basis for the transition first needs to be well researched; through an examination of what the literature is showing about curriculum renewal, and from experiences in trialling mechanisms that have been considered successful elsewhere. What differentiates this thesis is that within the theory of curriculum change, the question of what processes will speed up this type of transition is asked. Ultimately, other researchers will be able to trial this theorised account with engineering curriculum to gauge its efficacy (i.e. what the framework actually results in). Indeed this research question provides a potential trajectory for long term research as detailed in Chapter 7.

1.6 Overview of the following chapters

Building on the introduction provided in this chapter, the remainder of this dissertation document is structured as follows:

- In Chapter 2 the research design is outlined, including the overarching research methodology and the multiple-method iterative research approach used to learn from both the literature and personal experiences in the field. Ethical issues and considerations are summarised and limitations of the research are acknowledged.
- In Chapter 3 an investigation of higher education literature is presented, considering core elements of curriculum renewal, as well as issues surrounding the pace at which curriculum renewal is undertaken. A review of EESD literature is then presented with regard to emerging elements being used to assist in instances of rapid curriculum renewal. A review of four examples from other highly regulated professional disciplines is also presented, where rapid curriculum renewal is observed to have been undertaken, namely law, business, nursing and medicine. The chapter is concluded with a summary of six emerging elements that are informing rapid curriculum renewal and supporting requirements.
- In Chapter 4 a summary of reflexive inquiry into personal experiences related to rapid curriculum renewal is presented. The summary follows a questioning profile for each project considered as a lecturer and researcher. The findings are used to further inform the emerging elements distilled from the literature review, and to inform an emerging model for rapid curriculum renewal.
- In Chapter 5 the process of peer-reviewing the set of elements by engineering educators in Australia and internationally is summarised, highlighting key findings and additional questions posed that further inform the study.
- In Chapter 6, a model of rapid curriculum renewal is proposed, which extends the existing theory of curriculum renewal and ‘curriculum in context’, including four conceptual areas that must be considered. The model is then discussed with regard to implementation considerations, from the perspective of each of the elements of curriculum renewal.
- In Chapter 7 a summary is provided of what this thesis has confirmed from the existing literature on curriculum renewal, and the process of reflective inquiry and peer review. Conclusions are presented with regard to what this thesis extends, and what it refutes. A number of propositional statements are presented for further research and implications of the findings for accrediting bodies, higher education providers and national policy development are discussed.

1.7 Conclusion

In this chapter, a review of literature regarding 21st Century challenges found strong evidence of a critical and extra-ordinary role for all professions to urgently help society address a multitude of emerging issues of sustainable development. The literature review also found clear evidence around the world of the higher education sector facing increasing pressure from a variety of sources, including professional bodies, industry, government, and prospective students, to urgently equip graduates with knowledge and skills to address such challenges. Education for sustainable development (ESD) was defined as increasing the capacity of individuals, groups or organisations to contribute to sustainable development, through content and skills acquisition.

Among the professions, it was evident from the literature that engineering is considered a major potential contributor to finding solutions. There was also substantial evidence of awareness within the engineering professional and academic community that capacity building through engineering education for sustainable development (EESD) will be critical to ensure that the engineering community can meet such expectations. However, the review found clear evidence of concern by significant engineering bodies that higher education systems are failing to keep pace with such emerging demands. A time lag dilemma was observed for the higher education sector, particularly in engineering, whereby the timeframe for producing graduates with the required knowledge and skills lags behind the demand for graduates with such knowledge and skills – and also the timeframe by which professionals are expected to acquire this increased capability.

Within this context, there exist a variety of market, information and institutional catalysts acting to accelerate curriculum renewal, observed through the literature review to be interacting with barriers to such renewal in complex ways. Associated with the drivers and barriers is an observed risk and reward dynamic for engineering educators, where increasing levels of commitment were perceived to lead to increasing rewards and reduced risk. This increasing awareness of the benefits of acting quickly to undertake curriculum renewal is a further indicator that engineering educators may soon be attempting to undertake rapid curriculum renewal.

In conclusion, a focus on EESD is considered to be appropriate for the research with future potential application to a variety of other disciplines facing similar urgent and challenging circumstances, given: the insights into the key role of the engineering profession in addressing urgent and challenging sustainable development issues; the identified time lag dilemma facing engineering education; emerging timeframe catalysts; and the current gap in guidance on how to undertake rapid curriculum renewal.

References

[1] Brown, L. (2007) *Plan B 3.0: Mobilising to Save Civilisation*, W.W. Norton & Company, New York, www.earth-policy.org/Books/PB3/Contents.htm, accessed 12 May 2009.

[2] UNSD (2007) *International Civil Aviation Yearbook: Civil Aviation Statistics of the World*, UNSD, http://geodata.grid.unep.ch/, accessed 20 August 2008.

[3] OECD (2001) *OECD Environmental Outlook for the Chemicals Industry*, Organisation for Economic Co-operation and Development, Paris.

[4] UNCTAD (2006) 'Review of Maritime Transport 2006', United Nations Conference on Trade and Development, New York and Geneva, p48, www.unctad.org/en/docs/rmt2006_2006_en.pdf in GEO4, accessed 12 May 2008.

[5] United Nations Environment Programme (2008) *Green Jobs: Towards Decent Work in a Sustainable, Low-Carbon World*, United Nations.

[6] Brown, L. (2007) *Plan B 3.0: Mobilising to Save Civilisation*, W.W. Norton & Company, New York, pp117, 208.

[7] United Nations (2002) *Report of the World Summit on Sustainable Development*, United Nations, Johannesburg, South Africa, 26 August – 4 September 2002.

[8] Calculated from US Geological Survey, Mineral Commodity Summaries 2007, cited in Brown, L. (2007) *Plan B 3.0: Mobilising to Save Civilisation*, W.W. Norton and Company, New York, p43.

[9] WRI (2005) *World Resources 2005: The Wealth of the Poor-Managing Ecosystems to Fight Poverty*, World Resources Institute, in collaboration with the UNDP, UNEP and the World Bank, Washington, DC.

[10] Postel, S. (1999) *Pillar of Sand*, W.W. Norton & Company, New York, pp13-21.

[11] World Bank, (2007) 'Cost of Pollution in China - Economic Estimates of Physical Damages', The World Bank State Environmental Protection Administration, People's Republic of China, http://siteresources.worldbank.org/INTEAPREGTOPENVIRONMENT/Resources/China_Cost_of_Pollution.pdf, accessed 25 October 2008.

[12] IPCC (2007) *Climate Change 2007: Impacts, Adaptation & Vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

[13] Stern, N. (2006) *The Stern Review: The Economics of Climate Change*, Cambridge University Press, Cambridge.

[14] Stern, N. (2006) *The Stern Review: The Economics of Climate Change*, Cambridge University Press, Cambridge.

[15] Gore, A. (2006) *An Inconvenient Truth*, Rodale Books, US.

[16] The Natural Edge Project (2007) 'Action on climate change can help business competitiveness and economic growth – Executive Summary', A call for leadership in supporting a Climate Change Framework for Australia to participants of the '8th National Business Leaders Forum on Sustainable Development, National Business Leaders Forum on Sustainable Development, 'Leading the Change: Sustainable Business in Action', 21-22 May, Customs House, Brisbane.

[17] Smith, M., Hargroves, K. and Desha, C. (2010) Chapter 7, in *Cents and Sustainability - Securing Our Common Future by Decoupling Economic Growth from Environmental Pressures*, Earthscan, London.

[18] Stern, N. (2006) *The Stern Review: The Economics of Climate Change*, Cambridge University Press, Cambridge.

[19] Smith, M., Hargroves, K. and Desha, C. (2010) Chapter 1, in *Cents and Sustainability - Securing Our Common Future by Decoupling Economic Growth from Environmental Pressures*, Earthscan, London.

[20] Diamond, J. (2005) *Collapse: How Societies Choose to Fail or Succeed*, Penguin Books, New York.

[21] World Commission on Environment and Development (1987) *Our Common Future*, Oxford University Press, Oxford, p113.

[22] UNEP (2007) *Global Environment Outlook: Environment for development (GEO-4) report*, United Nations Environment Program.

[23] Orr, D. (1994) *Earth in Mind*, Washington DC, Island Press, p27.

[24] World Commission on Environment and Development (1987) *Our Common Future*, Oxford University Press, Oxford, p113.

[25] O'Connor, I. (2006) 'Earth Dialogues Dinner', Keynote Address by the Vice Chancellor of Griffith University, Brisbane.

[26] UN General Assembly (2002) 'Proclamation of the Decade of Education of Sustainable Development (2005 - 2014)', 57th Session, UN General Assembly, www.desd.org/, accessed 20 August 2008.

[27] McKeown, R. (2002) 'ESD Toolkit', www.esdtoolkit.org/, accessed 20 December 2009.

[28] Tilbury, D. and Wortman, D. (2004) *Engaging People in Sustainability,* The World Conservation Union, Island Press.

[29] Von Weisacker, E., Hargroves, K., Smith, M. and Desha, C. (2010) Factor 5: Achieving 80 percent improvements in resource productivity, Earthscan Press, London.

[30] Stasinopoulos, P., Hargroves, K., Smith, M. and Desha, C. (2010) *Whole System Design: A Systems Approach to Engineering*, Earthscan Press, London.

[31] Birkeland, J. (2010) *Net Positive Development*, Earthscan Press, London.

[32] Smith, M., Hargroves, K. and Desha, C. (2010) Chapter 3, in *Cents and Sustainability - Securing Our Common Future by Decoupling Economic Growth from Environmental Pressures*, Earthscan, London.

[33] Developed by The Natural Edge Project in considering opportunities for companies and the HEI sector, see also Desha, C. and Hargroves, K. (In Press) Engineering Education & Sustainable Development: A Guide for Rapid Curriculum Renewal, The Natural Edge Project and Earthscan Press, London.

[34] Association of University Leaders for a Sustainable Future (1992) *The Talloires Declaration: 10 Point Action Plan*, Association of University Leaders for a Sustainable Future, www.pb.unimelb.edu.au/ehs/ehs/environmenprogram/Talloires.pdf, accessed 12 July 2008.

[35] Report and Declaration of the Presidents Conference 1990, in Shriberg, M. and Tallent, H. (2003) 'Beyond Principles: Implementing the Talloires Declaration', Association of University Leaders for a Sustainable Future (ULSF) Presented at Greening of the Campus V: Connecting to Place, September, 2003, Ball State University, Muncie, Indiana, USA, p1, www.ulsf.org/pdf/ShribergTallentFinal.pdf, accessed 12 July 2008.

[36] United Nations (2002) *Report of the World Summit on Sustainable Development*, United Nations, Johannesburg, South Africa, 26 August – 4 September 2002.

[37] Parliamentary Commissioner for the Environment (2004) *See Change: Learning and education for sustainability*, Wellington, Parliamentary Commissioner for the Environment.

[38] UNESCO (1997) 'Thessaloniki Declaration', International Conference on Environment and Society Education and Public Awareness for Sustainability, UNESCO and the Government of Greece, 8-12 December 1997.

[39] UNESCO (1998) 'World Declaration on Higher Education for the Twenty-First Century: Vision and Action', World Conference on Higher Education, UNESCO, Paris, 9 October 1998.

[40] United Nations (2000) *The Earth Charter*, United Nations, www.earthcharter.org/, accessed 29 August 2008.

[41] GHESP (2002) 'The Lüneburg Declaration on Higher Education for Sustainable Development', Global Higher Education for Sustainability Partnership, International COPERNICUS Conference, University of Lüneburg, 8-10 October 2001.

[42] United Nations University, United Nations Educational, Scientific and Cultural Organization, International Association of Universities, Third World Academy of Sciences, African Academy of Science, Science Council of Asia, International Council for Science, World Federation of Engineering Organizations, Copernicus-Campus, Global Higher Education for Sustainability Partnership, and University Leaders for a Sustainable Future (2002) 'Ubuntu Declaration on Education and Science and Technology for Sustainable Development', World Summit on Sustainable Development, Johannesburg, September 2002.

[43] UN General Assembly (2002) 'Proclamation of the Decade of Education of Sustainable Development (2005 - 2014)' 57th Session, UN General Assembly, www.desd.org/, accessed 20 August 2008.

[44] International Association of Universities (undated) 'IAU', http://portal.unesco.org/education/en/ev.php-URL_ID=34754&URL_DO=DO_TOPIC&URL_SECTION=201.html, accessed 20 December 2009.

[45] The Campus Sustainability Assessment Project (undated) 'Introduction: The Sustainability Imperative and Higher Education: The Challenge of Sustainability', http://csap.envs.wmich.edu/pages/intro_imperative.html, accessed 27 June 2008.

[46] Kerr, J. (1968) *Changing the Curriculum*, Unibooks, University of London Press Ltd, p14.

[47] Midwinter, J.E. (2000) 'Something old, something new and something just in time: Dilemmas for EE education and Training', *Engineering Science and Education Journal*, vol 5, pp219-230.

[48] The Australian Research Institute in Education for Sustainability (ARIES) website, http://www.aries.mq.edu.au/about/, accessed 28 January 2010.

[49] Tilbury, D., Keogh, A., Leighton, A. and Kent, J. (2005) *A National Review of Environmental Education and its Contribution to Sustainability in Australia: Further and Higher Education*, Australian Government Department of the Environment and Heritage and Australian Research Institute in Education for Sustainability (ARIES), Canberra, Volume 5.

[50] Parliamentary Commissioner for the Environment (2004) *See Change: Learning and education for sustainability*, Wellington, New Zealand.

[51] Rensburg, E., Lotz Sisitka, H. and Mosidi, S. (2001) *Environmental Learning Across NQF*, Department of Environmental Affairs and Tourism, South Africa.

[52] Sustainable Development Education Panel (2002) *Learning to Last: Business and Sustainable Development - a* Learning *Guide for Sector Skills Councils*, UK Government Department for Environment, Food and Rural Affairs. http://www.defra.gov.uk/environment/sustainable/educpanel/learnguide/index.htm, accessed 21 January 2010.

[53] Forum for the Future (2004) 'Tip for Top in Higher Education: Forum's Learning in Action conference pushes the SD solutions', *Green Futures*, 14 March 2004, www.forumforthefuture.org.uk/greenfutures/articles/601773, accessed 12 May 2008.

[54] UNU-UNESCO (2006) 'Setting the Stage for a Strategic Research Agenda for the UNDESD', Joint Workshop 20 – 22 February 2006, UNESCO, Paris.

[55] Hatfield-Dodds, S., Turner ,G., Schandl, H. and Doss, T. (2008) *Growing the green collar economy: skills and labour challenges in reducing our greenhouse emissions and national environmental footprint*, report to the Dusseldorp Skills Forum, June 2008, CSIRO Sustainable Ecosystems, Canberra.

[56] PricewaterhouseCoopers (PWC) (2008) *Carbon countdown: a survey of executive opinion on climate change in the countdown to a carbon economy*, PWC.

[57] Proudfoot Consulting (2007) *Meeting the Corporate Energy Challenge: Are Companies Walking the Talk on Energy Efficiency?,* Proudfoot Consulting.

[58] Australian Industry Group (AIG) (2007) *Environmental Sustainability and Industry, Road to a Sustainable Future*, AIG, Australia.

[59] Carroll, W. (1992) 'World Engineering Partnership, for Sustainable Development', *Journal of Professional Issues in Engineering, Education and Practice,* vol 119, Issue 3, American Society of Civil Engineers, pp238-240.

[60] Ridley, T. and Ir. Lee Yee-Chong, D. (2002) 'Engineering and Technology for Sustainable Development', 2002 World Summit for Sustainable Development, Johannesburg and World Federation of Engineering Organisations' Committee on Technology, www.wfeo-comtech.org, accessed 18 July 2008.

[61] National Academy of Engineering (1998) 'The Urgency of Engineering Education Reform', *The Bridge – Frontiers of Engineering*, vol 28, no 1, Spring 1998, www.nae.edu/nae/bridgecom.nsf/weblinks/NAEW-4NHMKV?OpenDocument, accessed 8 February 2009.

[62] Borri, C. (2008), 'International Federation of Engineering Organisations: Presidents Message', www.ifees.net/about/message.cfm, accessed 31 July 2008.

[63] Cortese, A. (2007) 'Higher Education Leadership in Reversing Global Warming and Creating a Healthy, Just and Sustainable Society', a presentation to the Annual Meeting of the Annapolis Group, 19 June 2007, www.presidentsclimatecommitment.org/html/TonyCorteseSpeech-AnnapolisGroupmeeting.pdf, accessed 3 July 2008.

[64] The Royal Academy of Engineering (2007) *Educating Engineers for the 21st Century*, The Royal Academy of Engineering, London.

[65] WFEO (undated) 'Engineers and Sustainable Development – Engineering Progress', www.iies.es/FMOI-WFEO/desarrollosostenible/main/progress.htm, accessed 12 May 2008.

[66] Rajai, M. and Johnson, K. (2001) 'Creating new engineers for the new millennium', *Industry and Higher Education*, vol 15, no 5, pp349-352.

[67] Grear, B. (2008) Personal Communications with Barry Grear, Former President of the Institution of Engineers Australia, and incoming President for the World Federation of Engineering Organisations, 29 August 2008.

[68] Yusoff, S. (2005) 'The Need to Review Engineering Education for Achieving Sustainable Development', *Journal Pendidikan 2005,* Universiti Malaya, pp41-49, 45.

[69] Brown, L. (2007), *Plan B 3.0: Mobilising to Save Civilisation*, W.W. Norton & Company, New York, p202.

[70] Cascio, J. (2005a) 'White Light, Less Heat', *World Changing.com*, 25 October 2005, www.worldchanging.com/archives/003669.html, accessed 26 September 2008.

[71] The World Sustainable Building Conference in 2008 (SB08) provides numerous examples of green building innovations. See www.sb08melbourne.com/, accessed 26 September 2008.

[72] Cascio, J. (2005b) 'Green City China', *World Changing.com*, 13 September 2005, www.worldchanging.com/archives/003475.html, accessed 10 September 2008. Further information about the project is also available at www.arup.com/eastasia/project.cfm?pageid=7047, accessed 26 September 2008.

[73] Beder, S. (1997) *The New Engineer: Management and Professional Responsibility in a Changing World*, Macmillan Education Australia Ltd Publishing, Chapter 9: 'Technology and the Environment', pp195-224.

[74] WFEO (2002) *Engineers and Sustainable Development*, World Federation of Engineering Organisations' Committee on Technology.

[75] Sauvé, L. (1996) 'Environmental Education and Sustainable development: Further Appraisal', *Canadian Journal of Environmental Education,* vol 1, pp1-34.

[76] Fien, J. (2002) 'Advancing Sustainability in Higher Education – Issues and Opportunities for Research', *International Journal of Sustainability in Higher Education*, vol 3, no 3, pp243-253.

[77] Leal Filho, W. (ed) (2002) Teaching Sustainability at Universities: Towards curriculum greening, Peter Lang.

[78] Sterling, S. (2003) *Sustainable Education: Re-visioning Learning and Change,* Schumacher Briefings 6, Green Books, Darlington.

[79] Corcoran, P. and Wals, A. (eds) (2004) *Higher Education and the Challenges of Sustainability: Problematics, Promise, and Practice*, Kluwer Academic Publishers, The Netherlands.

[80] Parkin, S., Johnston, A., Buckland, H., Brookes, F. and White, E. (2004) *Learning and Skills for Sustainable Development: Developing a Sustainability Literate Society - Guidance for Higher Education Institutions*, Higher Education Partnership for Sustainability (HEPS) / Forum for the Future, London.

[81] Cortese, A. (2003) 'The Critical Role of Higher Education in Creating a Sustainable Future', *Planning for Higher Education*, March-May 2003.

[82] Blewitt, J. and Cullingford, C. (2004) *The Sustainability Curriculum: The Challenge for Higher Education,* Earthscan, London.

[83] Dawe, G., Jucker, R. and Martin, S. (2005) *Sustainable Development in Higher Education: Current Practice and Future Developments*, A report for The Higher Education Academy, November 2005.

[84] Jansen, L. (2002) 'The Challenge of Sustainable Development', *Journal of Cleaner Production*, vol 11, Issue 3, pp231-245.

[85] Mulder, K. (2005) 'Engineering Education in Sustainable Development', Guest Editorial, *International Journal of Sustainability in Higher Education*, vol 5, Issue 3.

[86] Mulder, K. (2004) 'Engineering Education in Sustainable Development: Sustainability as a tool to open up the windows of engineering education', *International Journal of Business Strategy and the Environment,* Vol 13, Issue 4, pp275–285.

[87] Ferrer-Balas, D. and Mulder, K. (2005) 'Engineering Education in Sustainable Development', Guest Editorial, *International Journal of Sustainability in Higher Education*, vol 6, Issue 3.

[88] Holmberg, J., Svanström, M., Peet, D., Mulder, K., Ferrer-Balas, D. and Segalàs, J. (2008) 'Embedding Sustainability in Higher Education through Interaction with Lecturers: Case studies from three European Technical Universities', *European Journal of Engineering Education*, vol 33, no 3, pp271-282.

[89] Carroll, W. (1993) 'World Engineering Partnership for Sustainable Development', *Journal of Professional Issues in Engineering Education and Practice*, vol 119, no 3, pp238-240.

[90] Cortese, A. (1997) 'Engineering education for a sustainable future', Engineering Education and Training for Sustainable Development Conference, Paris, France.

[91] Crofton, F. (2000) 'Educating for sustainability: opportunities in undergraduate engineering', *Journal of Cleaner Production*, vol 8, pp397-405.

[92] Ashford, N. (2004) 'Major challenges to engineering education for sustainable development: What has to change to make it creative, effective, and acceptable to the established disciplines?', *International Journal of Sustainability in Higher Education*, vol 4, Issue 3, pp239-250.

[93] Azapagic, A., Perdan, S. and Clift, R. (2000) 'Teaching sustainable development to engineering students', *International Journal of Sustainability in Higher Education*, vol 1, Issue 3, pp267-279.

[94] Azapagic, A., Perdan, S. and Clift, R. (eds) (2004) *Sustainable Development in Practice: Case Studies for Engineers and Scientists*, Wiley Press, New York.

[95] McKeown, R., Hopkins, C. and Rizzi, R. (2002) *Education for Sustainable Development Toolkit*, Version 2, July 2002, www.esdtoolkit.org, accessed 20 December 2008.

[96] Pritchard, J. and Baillie, C. (2006) 'How can engineering education contribute to a sustainable future?', *European Journal of Engineering Education*, vol 31, no 5, pp555-565.

[97] Allenby, B., Allen, D. and Davidson, C. (2007) 'Teaching Sustainable Engineering', *Journal of Industrial Ecology*, vol 11, no 1, pp8-10.

[98] Timpson, W., Dunbar, B., Kimmel, G., Bruyere, B., Newman, P. and Mizia, H. (2009) *147 Practical Tips for Teaching Sustainability: Connecting the Environment, the Economy, and Society*, Atwood Publishing.

[99] Newman, J. and Fernandez, L. (2007) *Strategies for Institutionalizing Sustainability in Higher Education: Report on the Northeast Campus Sustainability Consortium 3rd Annual Conference and International Symposium*, Yale School of Forestry and Environmental Studies, April 2007.

[100] Steinemann, A. (2003) 'Implementing sustainable development through problem-based learning: pedagogy and practice', *Journal of Professional Issues in Engineering Education and Practice*, vol 129, no 4, pp216-24.

[101] Lehmann, M., Christensen, P., Du, X. and Thrane, M. (2008) 'Problem-oriented and project-based learning (POPBL) as an innovative learning strategy for sustainable development in engineering education', *European Journal of Engineering Education*, vol 33, no 3, pp283-295.

[102] Crawley, E., Malmqvist, J., Östlund, S. and Brodeur, D. (2007) *Rethinking Engineering Education: The CDIO Approach,* Springer, New York.

[103] Rowe, D. (2007) 'Policy Forum Sustainability: Education for a Sustainable Future', *Science*, vol 317, no 5836, pp323-324.

[104] Stephens, J. and Graham, A. (2009) 'Toward an empirical research agenda for sustainability in higher education: exploring the transition management framework, *Journal of Cleaner Production.*

[105] Steinfeld, J. and Takashi, M. (2009) 'Special Feature Editorial: Education for sustainable development - the challenge of trans-disciplinarity', *Journal of Sustainability Science*, Springer, vol 4, no 1, pp1-2.

[106] Holdsworth, S., Wyborn, C., Bekessy, S. and Thomas, I. (2008) 'Professional development for education for sustainability: How advanced are Australian universities?', *International Journal of Sustainability in Higher Education*, Vol 9, Issue 2, pp131-146.

[107] NAE (2005) 'Educating the Engineer of 2020: Adapting Engineering Education to the New Century', Committee on the Engineer of 2020, Phase II, Committee on Engineering Education, National Academy of Engineering of the National Academies, Washington DC.

[108] Marjoram, T. (2006) 'Report and Recommendations of Workshop', International Workshop: Engineering Education for Sustainable Development, Tsinghua University, Beijing, 31 October – 2 November, 2006, www.wfeo.org/documents/download/EESDTsinghuaRecommsActionNov06V3.doc, accessed 6 August 2008.

[109] The Royal Academy of Engineering (2007) *Educating Engineers for the 21st Century*, The Royal Academy of Engineering, London.

[110] HEFC (2007) 'HEFC Strategic Review of sustainable Development in Higher Education in England', Report to the Higher Education Funding Council for England by the Policy studies Institute, PA Consulting Group and the Centre for Research in Education and the Environment.

[111] The Chinese Academy of Engineering (2004) 'The International Forum on Engineering Technology and Sustainable Development', held in conjunction with the 8th East Asia Round Table Meeting of Engineering Academics Suzhou, China, 31 October – 1 November, 2004.

[112] Kamp, L. (2006) 'Engineering education in sustainable development at Delft University of Technology', *Journal of Cleaner Production*, vol 14, Issues 9-11, pp 928-931.

[113] Mulder, K. (2004) 'Engineering Education in Sustainable Development: Sustainability as a tool to open up the windows of engineering education', *International Journal of Business Strategy and the Environment,* Vol 13, Issue 4, pp275–285.

[114] Lundqvist, U. and Svanström, M. (2008) 'Inventory of content in basic courses in environment and sustainable development at Chalmers University of Technology in Sweden', *European Journal of Engineering Education*, vol 33, Issue 3, pp355-364.

[115] Fenner, R., Ainger, C., Cruickshank, H. and Guthrie, P. (2005) 'Embedding sustainable development at Cambridge University Engineering Department', *International Journal of Sustainability in Higher Education*, vol 6, Issue 3, pp229-241.

[116] Humphries-Smith, T. (2008) 'Sustainable design and the design curriculum', *Journal of Design Research*, vol 7 no 3, pp259-274.

[117] Lozano, R. (2009) 'Diffusion of sustainable development in universities' curricula: an empirical example from Cardiff University', *Journal of Cleaner Production*, doi:10.1016/j.jclepro.2009.07.005.

[118] Fletcher, J., Drahun, G., Davies, P. and Knowles, P. (2008) 'The teaching of sustainable development at Aston University', proceedings of the 2008 International Symposium for Engineering Education, Dublin City University, Ireland.

[119] Ferrer-Balas, D., Bruno, J., de Mingo, M. and Sans, R. (2004) 'Advances in education transformation towards sustainable development at the Technical University of Catalonia, Barcelona', *International Journal of Sustainability in Higher Education*, vol 5, Issue 3, pp251-266.

[120] Allenby, B., Folsom Murphy, C., Allen, D. and Davidson, C. (2009) 'Sustainable engineering education in the United States', *Journal of Sustainability Science*, vol 4, no 1, pp7-15.

[121] Epstein, A., Bras, R. and Bowring, S. (2009) 'Building a freshman-year foundation for sustainability studies: Terrascope, a case study', *Journal of Sustainability Science*, vol 4, no 1, pp37-43.

[122] Mihelcic, J., Phillips, l. and Watkins, D. (2006) 'Integrating a Global Perspective into Education and Research: Engineering International Sustainable Development', *Environmental Engineering Science*, vol 23, Issue 3, pp426-438.

[123] Lozano-Garcià, F., Gàndara, G., Perrni, O., Manzano, M., Hernàndez, D. and Huisingh, D. (2008) 'Capacity building: a course on sustainable development to educate the educators', *International Journal of Sustainability in Higher Education*, vol 9, no 3, pp257-281.

[124] Wright, S., Habit, E., Adlerstein, S., Parra, O. and Semrau, J. (2009) 'Graham Scholars Program: sustainability education through an interdisciplinary international case study', *Journal of Sustainability Science*, vol 4, no 1, pp29-36.

[125] Onuki, M. and Mino, T. (2009) 'Sustainability education and a new master's degree, the master of sustainability science: the Graduate Program in Sustainability Science (GPSS) at the University of Tokyo', *Journal of Sustainability Science*, vol 4, no 1, pp55-59.

[126] Uwasu, M., Yabar, H., Hara, K., Simoda, Y. and Saijo, T. (2009) 'Educational initiative of Osaka University in sustainability science: mobilizing science and technology towards sustainability', *Journal of Sustainability Science*, vol 4, no 1, pp45-53.

[127] Xu, K. (2008) 'Engineering education and technology in a fast-developing China', *Journal of Technology in Society,* Vol 30, pp265–274.

[128] Olorunfemi, A. and Dahunsi, B. (2004) 'Towards a Sustainable Engineering Education and Practice in Nigeria', proceedings of the SEFI 2004 Annual Congress, *The Golden Opportunity for Engineering Education*.

[129] Ramjeawon, T. (2008) 'Sustainable Development: The Enabling Role of the Engineer' in Institution of Engineers Mauritius (2008) 60th Anniversary Commemorative Issue. The Journal of the Institution of Engineers Mauritius, October 2008. (Professor Toolseeram Ramjaeawon, Faculty of Engineering, University of Mauritius) pp12-17.

[130] Davis, R. and Savage, S. (2008) 'Built Environment and Design in Australia: Challenges and Opportunities for Professional Education', proceedings of the 20th Australasian Association of Engineering Education conference, 6-9 December, Adelaide.

[131] Goh, S. (2009) 'A New Paradigm for Professional Development Framework and Curriculum Renewal in Engineering Management Education: A Proposal for Reform', proceedings of the 20th Australasian Association of Engineering Education conference, 6-9 December, Adelaide.

[132] Bryce, P., Johnston, S. and Yasukawa, K. (2004) 'Implementing a program in sustainability for engineers at University of Technology, Sydney: a story of intersecting agendas', *International Journal of Sustainability in Higher Education*, vol 5, no 3, pp267-277.

[133] Mitchell, C. (2000) *'Integrating Sustainability in Chemical Engineering Practice and Education: Concentricity and its Consequences'*, Institution of Chemical Engineers, *Trans IChemE*, vol 78, Part B, July 2000.

[134] Carew, A. and Therese, S. (2007) 'EMAP: Outcomes from Regional Forums on Graduate Attributes in Engineering', proceedings of the 2007 AaeE Conference, Melbourne.

[135] Koth, B. and Woodward, M. (2009) 'Civil engineering education for sustainability: faculty perceptions and result of an Australian course audit', proceedings of the 20th Australasian Association of Engineering Education conference, 6-9 December, Adelaide, pp776-782.

[136] Daniell, T. and Maier, H. (200) 'Embedding Sustainability in Civil and Environmental Engineering Courses', Proceedings of the 2005 ASEE/AaeE 4th Global Colloquium on Engineering Education, Sydney.

[137] Carew, A. and Lindsay, E. (2009) 'Curriculum Lifeboat: a process for rationalising engineering course content', proceedings of the 20th Australasian Association of Engineering Education conference, 6-9 December, Adelaide.

[138] Short case study summaries of the University of Technology Sydney (UTS), and the Royal Melbourne Institute of Technology (RMIT) are provided through the UTS Centre for Learning and Teaching website: http://www.clt.uts.edu.au/Theme.ident.grad.att.htm (accessed 16 July 2008).

[139] Mann, S. and Smith L. (2007) 'Computing Education for Sustainability', proceedings of the 20th Annual Conference of the National Advisory Committee on Computing Qualifications (NACCQ 2007), Nelson, New Zealand.

[140] Pérez-Foguet, A., Oliete-Josa, S. and Saz-Carranza, A. (2005) 'Development education and engineering: A framework for incorporating reality of developing countries into engineering studies', *International Journal of Sustainability in Higher Education*, vol 6, Issue 3, pp278-303.

[141] Boyle, C. (2004) 'Considerations on educating engineers in sustainability', *International Journal of Sustainability in Higher Education*, Vol 5, Issue 2, pp147-155.

[142] Steinfeld, J. and Takashi, M. (2009) 'Education for sustainable development: the challenge of trans-disciplinarity', *Journal of Sustainability Science*, vol 4, no 1, pp1-2.

[143] Kumazawa, T., Saito, O., Kozaki, K., Matsui, T. and Mizoguchi, R. (2009) 'Toward knowledge structuring of sustainability science based on ontology engineering', *Journal of Sustainability Science*, vol 4, no 1, pp99-116.

[144] Mihelcic, J., Crittenden, J., Small, M., Shonnard, D., Hokanson, D., Zhang, Q., Chen, H., Sorby, S., James, V., Sutherland, J. and Schnoor, J. (2003) 'Sustainability Science and Engineering: The Emergence of a New Metadiscipline', *Environmental Science Technologies*, vol 37, pp5314-5324.

[145] Mihelcic, J., Crittenden, J., Small, M., Shonnard, D., Hokanson, D., Zhang, Q., Chen, H., Sorby, S., James, V., Sutherland, J. and Schnoor, J. (2003) 'Sustainability Science and Engineering: The Emergence of a New Metadiscipline', *Environmental Science Technologies*, vol 37, pp5314-5324.

[146] UNEP, WFEO, WBCSD, ENPC (1997) 'Engineering Education and Training for Sustainable Development', Report of the joint UNEP, WFEO, WBCSD, ENPC Conference, Paris, France, 24–26 September 1997, Chapter 10: 'Appendices - IV WFEO Survey', p42.

[147] Azapagic, A., Perdan, S. and Shallcross, D. (2005) 'How much do engineering students know about sustainable development? The findings of an international survey and possible implications for the engineering curriculum', *European Journal of engineering Education*, vol 30, Issue 1, pp1-19.

[148] Azapagic, A., Perdan, S. and Shallcross, D. (2005) 'How much do engineering students know about sustainable development? The findings of an international survey and possible implications for the engineering curriculum', *European Journal of engineering Education*, vol 30, Issue 1, p1.

[149] Thomas, I. and Nicita, J. (2002) 'Sustainability Education in Australian Universities', *Environmental Education Research*, vol 8, Issue 4, pp475-492.

[150] The Alliance for Global Sustainability (2006) *The Observatory: Status of Engineering Education for Sustainable Development in European Higher Education*, EESD-Observatory, Technical University of Catalonia, Spain, p3, www.upc.edu./eesd-observatory/, accessed 17 July 2008.

[151] Meddings, L. and Thorne, T. (2008) 'Engineers of 21st Century: Engineering Education Project: What I Wish I'd Learnt at University', Report to the Forum for the Future's Engineers of the 21st Century programme, ARUP, Australia.

[152] Desha, C. and Hargroves, K. (2009) 'Surveying the State of Higher Education in Energy Efficiency, in Australian Engineering Curriculum', *Journal of Cleaner Production*, Elsevier, doi:10.1016/j.jclepro.2009.07.004.

[153] Allen, D., Allenby, B., Bridges, M., Crittenden, J., Davidson, C., Hendrickson, C., Matthews, C., Murphy, C. and Pijawka, D. (2008) *Benchmarking Sustainability Engineering Education: Final Report*, EPA Grant X3-83235101-0, Centre for Sustainable Engineering, Pittsburgh, America, www.csengin.org/benchmark.htm, accessed 12 March 2009.

[154] Allen, D., Allenby, B., Bridges, M., Crittenden, J., Davidson, C., Hendrickson, C., Matthews, C., Murphy, C. and Pijawka, D. (2008) *Benchmarking Sustainability Engineering Education: Final Report*, EPA Grant X3-83235101-0, Centre for Sustainable Engineering, Pittsburgh, America, p3, www.csengin.org/benchmark.htm, accessed 12 March 2009.

[155] The Alliance for Global Sustainability (2008) *The Observatory: Status of Engineering Education for Sustainable Development in European Higher Education*, EESD-Observatory, Technical University of Catalonia, Spain.

[156] Ferer-Balas, D. and Mulder, K. (Guest Editors) (2005) Special Issue 'Engineering Education in Sustainable Development', *International Journal of Sustainability in Higher Education*, vol 6, Issue 3, Emerald Press.

[157] Lozano García, F., Kevany, K. and Huisingh, D. (Guest Editors) (2006) Special Issue 'Sustainability In Higher Education: What is Happening?', *Journal of Cleaner Production*, vol 14.

[158] Mulder, K., Bretelle-Desmazieres, D. and Foxley, D. (Guest Editors) (2008) 'Sustainable Development', Special Issue *European Journal of Engineering Education*, vol 33, Issue 3.

[159] Including annual and biennial conferences such as the International Conference on Engineering Education (ICEE) the Australasian Association of Engineering Education (AaeE) conference, the Global Colloquium on Engineering Education conferences hosted by the American Society for Engineering Education (ASEE) and the Engineering Education for Sustainable Development conference.

[160] NAE (2005) 'Educating the Engineer of 2020: Adapting Engineering Education to the New Century', Committee on the Engineer of 2020, Phase II, Committee on Engineering Education, National Academy of Engineering of the National Academies, Washington DC.

[161] Marjoram, T. (2006) 'Report and Recommendations of Workshop', International Workshop: Engineering Education for Sustainable Development, Tsinghua University, Beijing, 31 October – 2 November, 2006, www.wfeo.org/documents/download/EESDTsinghuaRecommsActionNov06V3.doc, accessed 6 August 2008.

[162] The Royal Academy of Engineering (2007) *Educating Engineers for the 21st Century*, The Royal Academy of Engineering, London.

[163] HEFC (2007) 'HEFC Strategic Review of sustainable Development in Higher Education in England', Report to the Higher Education Funding Council for England by the Policy studies Institute, PA Consulting Group and the Centre for Research in Education and the Environment.

[164] King, R. (2008) 'Addressing the Supply and Quality of Engineering Graduates for the New Century', Report to the Carrick Institute for Learning and Teaching in Higher Education Ltd, Sydney.

[165] Institution of Engineers Australia (1996) *Changing the Culture: Engineering Education into the Future*, Institution of Engineers Australia, Canberra.

[166] King, R. (2008) 'Addressing the Supply and Quality of Engineering Graduates for the New Century', Report to the Carrick Institute for Learning and Teaching in Higher Education Ltd, Sydney.

[167] Hargroves, K. and Smith, M. (2005) *The Natural Advantage of Nations: Business Opportunities, Innovation and Governance in the 21st Century*, Earthscan, London, p61.

[168] Hargroves, K. and Smith, M. (2005) *The Natural Advantage of Nations: Business Opportunities, Innovation and Governance in the 21st Century*, Earthscan, London, p61.

[169] Hargroves, K. and Smith, M. (2005) *The Natural Advantage of Nations: Business Opportunities, Innovation and Governance in the 21st Century*, Earthscan, London, p60.

[170] Levett-Therivel (2006) 'Sustainability carrots and sticks: the benefits and risks of sustainable development for HEIs', Report to HEFCE, www.hefce.ac.uk/Pubs/RDreports/2006/rd18_06/rd18_06.pdf, accessed 3 July 2008.

[171] Speicher, A. (1994) 'ASEE Project Report: Engineering Education for a Changing World Using Partnerships to Respond to New Needs in Engineering Education', *ASEE Prism*, vol 20, Issue 27.

[172] European Union (2002) *Directive on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment*, European Union.

[173] Environment Agency (2006) *Statutory Instrument 2006 No. 3315: The Waste Electrical and Electronic Equipment (Waste Management Licensing) (England and Wales) Regulations 2006*, Environment Agency, UK, www.opsi.gov.uk/si/si2006/20063315.htm, accessed 6 August 200.

[174] World Business Council for Sustainable Development (undated) 'homepage', www.wbcsd.org/, accessed 31 July 2008.

[175] UN Global Compact, UNEP and WBCSD (2007) 'Caring for Climate: The Business Leadership Platform', Business leaders statement issued at the *UN Global Compact Leaders Summit*, Geneva July, 2007, www.unglobalcompact.org/Issues/Environment/Climate_Change/index.html, accessed 3 July 2008.

[176] van der Veer, J. (2006), 'The Importance and Need for EESD: Re-engineering the Engineers', in The Alliance for Global Sustainability, *The Observatory: Status of Engineering Education for*

Sustainable Development in European Higher Education, 2006, EESD-Observatory, Technical University of Catalonia, Spain, p8, www.upc.edu./eesd-observatory/, accessed 17 July 2008.

[177] Porrit, J. (2007) 'Keynote Speech: Global Sustainability Forum: The Future for Engineering Education', http://www3.imperial.ac.uk/globalsustainability, accessed 20 August 2008.

[178] Environmental Leader (2009) 'Sustainability knowledge in demand', *Environmental Leader*, 25 March 2009, www.environmentalleader.com/2009/03/25/sustainability-knowledge-in-demand/, accessed 12 May 2009.

[179] James, R. (2002) "Students' Changing Expectations of Higher Education and the 'Consequences of Mismatches with Reality'", in Responding to Student Expectations, Paris, OECD.

[180] IFEES (2008) 'Aligning Engineering Education initiatives for a Knowledge Economy', 2nd IFEES Global Engineering Education Summit, Cape Town, South Africa, 19-10 October 2008, www.aeea.co.za/i/i//IFEES2008SummitProgram.pdf, accessed 1 September 2008.

[181] Meddings, L. and Thorne, T. (2008) "Engineers of 21st Century: Engineering Education Project 'What I Wish I'd Learnt at University'", Report to the Forum for the Future's Engineers of the 21st Century programme. Final Report, Ove Arup and Partners, London.

[182] Leckstrom, J. (2008) 'Kaplan Releases New College Guide 2009 Featuring 25 Green Colleges and 10 Hot Green...' *PRNewswire,* Tuesday 5 August 2008, New York, www.reuters.com/article/pressRelease/idUS135812+05-Aug-2008+PRN20080805, accessed 30 October 2008.

[183] Alpay, E., Ahearn, A., Graham, R. and Bull, A. (2008) 'Student enthusiasm for engineering: charting changes in student aspirations and motivation', *European Journal of Engineering Education*, Vol 33, no 5, pp573-585.

[184] Alpay, E. (2008) Personal communication with Dr Esat Alpay, Senior Lecturer in Engineering Education, Imperial College, London, 13 September 2008.

[185] Grant, M. (2008) Personal Communication with Ms Michelle Grant, Project Manager, ETH Sustainability, Zurich, 14 August 2008.

[186] Marjoram, T. (2009) 'Foreword' in Stasinopoulos, P., Smith, M., Hargroves, K. and Desha, C., *Whole system Design: An Integrated Approach to Sustainable Engineering*, Earthscan, London.

[187] Engineers for a Sustainable World (2008) 'Mission Statement', www.esustainableworld.org/about/mission.asp, accessed 1 September 2008.

[188] King, R. (2008) 'Addressing the Supply and Quality of Engineering Graduates for the New Century', Report to the Carrick Institute for Learning and Teaching in Higher Education Ltd, Sydney, p43.

[189] Huisingh, D. (2008) Personal Communications with Professor Don Huisingh, Senior Scientist in Sustainable Development, the University of Tennessee, 6 November 2008.

[190] IIES (1992) 'Arusha Declaration: Statement by the World Federation of Engineering Organisations (WFEO) Environment and Development', The UNCED Conference, www.iies.es/FMOI-WFEO/desarrollosostenible/main/assets/ArushaDeclaration.doc, accessed 31 July 2008.

[191] World Commission on Environment and Development (1987) *Our Common Future*, Oxford University Press, Oxford.

[192] Elms, D. and Wilkinson, D. (1995) *Workshop: Fundamentals of Environmental Education in Engineering Education*, New Zealand.

[193] UNEP, WFEO, WBCSD, ENPC (1997) 'Engineering Education and Training for Sustainable Development', Report of the joint UNEP, WFEO, WBCSD, ENPC Conference, Paris, France, 24–26 September 1997, p4.

[194] Sustainability Taskforce (1997) *The Engineer's Response to Sustainable Development*, World Federation of Engineering Organizations.

[195] WFEO (undated) 'Engineers and Sustainable Development – Engineering Progress', www.iies.es/FMOI-WFEO/desarrollosostenible/main/progress.htm, accessed 12 May 2008.

[196] EESD (2004) 'Engineering Education for Sustainable Development: Declaration of Barcelona', International Conference Barcelona, 27-29 October, 2004, www.upc.edu/eesd-observatory/BCN%20Declaration%20EESD_english.pdf, accessed 12 July 2008.

[197] UNESCO (2004) 'The Shanghai Declaration on Engineering and the Sustainable Future', World Engineers' Convention, Shanghai, 5 November 2004, http://portal.unesco.org/science/en/ev.php-URL_ID=4146&URL_DO=DO_PRINTPAGE&URL_SECTION=201.html, accessed 6 August 2008.

[198] American Society of Engineering Education (2008) *7th Global Colloquium on Engineering Education*, American Society of Engineering Education, Cape Town, South Africa. Program, www.asee.org/conferences/international/2008/Program.cfm, accessed 1 September 2008.

[199] International Network for Engineering Education and Research (2008) 'ICEE 2008: New Challenges in Engineering Education and Research in the 21st Century', International Network for Engineering Education and Research, Pecs-Budapest, Hungary, 27-31 July 2008, http://icee2008hungary.net/main.php?menu=1, accessed 1 September 2008.

[200] WFEO (1997) *The Engineer's Response to Sustainable Development*, The World Federation of Engineering Organizations.

[201] Jones, D. (2004) 'Opening Address: Sustainability – The Greatest Challenge', 8th International Conference on Bulk Materials Storage, Handling and Transportation, Wollongong, Australia.

[202] Browne, J. (2007) *Catalyst*, UK Royal Academy of Engineering, London.

[203] King, J. (2007) 'Introduction', in RAE Working Party, *Educating Engineers for the 21st Century*, RAE, London.

[204] Taylor, P. (2008) Personal communications with Mr Peter Taylor, CEO, Institution of Engineers Australia.

[205] Grear, B. (2008) Personal communications with Mr Barry Grear, Former President of the Institution of Engineers Australia, and incoming President for the World Federation of Engineering Organisations, 29 August 2008.

[206] Xu, K. (2008) 'Engineering education and technology in a fast-developing China', *Technology in Society.* vol 30, p268.

[207] Engineers Australia (2000) *Engineering Code of Ethics*, Institution of Engineers Australia, Canberra.

[208] Xu, K. (2008) 'Engineering education and technology in a fast-developing China', *Technology in Society,* vol 30, p268.

[209] FIDIC (2004) 'Policy Statement: Consulting Engineers and the Environment', International Federation of Consulting Engineers, http://www1.fidic.org/about/statement04.asp, accessed 20 August 2008.

[210] UNEP (undated) 'Environment Management and Performance', www.unepie.org/scp/business/emp/index.htm, accessed 3 July 2008.

[211] International Council for Science (ICSU), World Federation of Engineering Organisations (WFEO), Third World Academy of Sciences (TWAS), the InterAcademy Panel (IAP) and the International Social Science Council (ISSC) (2001) 'Role and Contributions of the Scientific and Technological Community (S&TC) to Sustainable Development', Preparatory Process for the World Summit for Sustainable Development - Chapter 31 of Agenda 21.

[212] World Federation of Engineering Organisations (2007) *Engineers Response to Sustainable Development* http://www.iies.es/FMOI-WFEO/desarrollosostenible/main/assets/EngEducation.doc, accessed 31 July 2008.

[213] WFEO (2001) 'The WFEO Model Code of Ethics', www.wfeo.org/index.php?page=ethics, accessed 31 July 2008.

[214] Borri, C. (2008) 'International Federation of Engineering Organisations: Presidents Message', www.ifees.net/about/message.cfm, accessed 31 July 2008.

[215] King, R. (2008) 'Addressing the Supply and Quality of Engineering Graduates for the New Century', Report to the Carrick Institute for Learning and Teaching in Higher Education Ltd, Sydney, p29.

[216] Leonard, M., Beasley, D. Scales, K. and Elzinga, D. (1998) 'Planning for Curriculum Renewal and Accreditation Under ABET Engineering Criteria 2000', ASEE Annual Conference and Exposition. Seattle, Washington.

[217] Phillips, W., Peterson, G. and Aberle, K. (2000) 'Quality Assurance for Engineering Education in a Changing World', *International Journal of Engineering Education,* Great Britain, vol 15, no 2, pp97-103.

[218] Speicher, A. (1994) 'ASEE Project Report: Engineering Education for a Changing World Using Partnerships to Respond to New Needs in Engineering Education', ASEE Prism, pp20-27.

[219] Leonard, M. and Beasley, D. (1998) 'Planning for Curriculum Renewal and Accreditation Under ABET Engineering Criteria 2000', 1998 ASEE Annual Conference and Exposition, Seattle.

[220] Brown, K. (1998) 'SARTOR 97: the background and the looming shake-out for university engineering departments', *Journal of Engineering Science Education,* vol 7, Issue 1, pp41-48.

[221] European Network for Accreditation of Engineering Education (ENAEE) (undated) 'Presentation – Accreditation/ EUR-ACE', http://www.feani.org/webfeani/, accessed 21 December 2009.

[222] International Engineering Alliance (2007) 'Rules and Procedures: International Educational Accords', International Engineering Alliance, pp40-41.

[223] International Engineering Alliance (undated) 'Introduction', www.washingtonaccord.org/, accessed 15 June 2008.

[224] International Engineering Alliance (2007) *Rules and Procedures: International Educational Accords*, International Engineering Alliance, pp40-41.

[225] International Engineering Alliance (2007) *Rules and Procedures: International Educational Accords*, International Engineering Alliance, pp40-41.

[226] Basri, H., Che Man, A., Wan Badruzzaman, W. and Nor, M. (2004) 'Malaysia and Washington Accord: What It Takes For Full Membership', *International Journal of Engineering and Technology*, vol 1, no 1, pp64-73.

[227] Boyle, C. (2008) Personal Communication with Dr. Carol Boyle, Director of the International Centre for Sustainability Engineering and Research at the University of Auckland, 2 September 2008.

[228] Heywood, J. (2005) *Engineering Education Research and Development in Curriculum and Instruction*, Institute of Electrical and Electronics Engineers (IEEE), p4.

[229] Lype, G. (2006) 'Engineering education: Can India overtake China?', *Rediff News*, 9 June 2007, www.rediff.com/money/2006/jun/09bspec.htm, accessed 3 July 2008.

[230] The Chinese Academy of Engineering (2004) 'The International Forum on Engineering Technology and Sustainable Development', held in conjunction with the 8th East Asia Round Table Meeting of Engineering Academics Suzhou, China, 31 October – 1 November, 2004.

[231] Marjoram, T. (2006) 'Report and Recommendations of the Workshop',,International Workshop: Engineering Education for Sustainable Development, Tsinghua University, Beijing, 31 October – 2 November, 2006, www.wfeo.org/documents/download/EESDTsinghuaRecommsActionNov06V3.doc, accessed 6 August 2008.

[232] McKinsey Global Institute (2005) *The Emerging Global Labor Market*, McKinsey Global Institute, www.mckinsey.com/mgi/publications/emerginggloballabormarket/index.asp, accessed 3 July 2008.

[233] ABET (2007) *Criteria for Accrediting Engineering Programs: Effective for Evaluations During the 2008-2009 Accreditation Cycle*, Engineering Accreditation Commission. Incorporates all changes approved by the ABET Board of Directors as of November 3, 2007.

[234] UK Engineering Council (2004) 'UK Standard for Professional Engineering Competence', Chartered Engineer and Incorporated Engineer Standard, UK Engineering Council (Reprinted in 2005).

[235] The Authors research group, The Natural Edge Project, was incubated by Engineers Australia for three years before transferring to Griffith University and Australian National University in 2006.

[236] Engineers Australia (2007) 'Accreditation Management System', www.engineersaustralia.org.au/education/program-accreditation/accreditation-management-system/accreditation-management-system.cfm, accessed 15 June 2008.

[237] Engineers Australia (2004) *Stage 1 Competency Standards for Professional Engineers*, The Institution of Engineers Australia, Canberra.

[238] Crawley, E., Malmqvist, J., Ostlund, S. and Brodeur, D. (2007) *Rethinking Engineering Education: The CDIO Approach*, Springer Press, New York.

[239] Wedel, M., Malmqvist, J., Arehag, M. and Svanström M. (2008) 'Implementing Engineering Education for Environmental Sustainability into CDIO Programs', Proceedings of the 4th International CDIO Conference, June 16-19, 2008, Hogeschool Gent, Belgium.

[240] Hargroves, K., and Smith, M. (2005) *The Natural Advantage of Nations: Business Opportunities, Innovation and Governance in the 21st Century*, Earthscan, London, p61.

[241] Marjoram, T. (ed) (In Press) *UNESCO Report: Engineering - Issues and Challenges for Development*, Produced in conjunction with World Federation of Engineering Organisations (WFEO), International Council Academies of Engineering and Technological Sciences (CAETS), International Federation of Consulting Engineers (FIDIC).

[242] The Business Council Sustainable Growth Task Force (2004) *Beyond the Horizon: Short-Termism in Australia*, Business Council of Australia, www.bca.com.au/Content/101402.aspx, accessed 4 September 2008.

[243] The Business Council Sustainable Growth Task Force (2004) *Beyond the Horizon: Short-Termism in Australia*, Business Council of Australia, www.bca.com.au/Content/101402.aspx, accessed 4 September 2008.

[244] Greenwood, P. (2007) 'Helping Small Business Survive the Skill Shortage - an Australian Perspective', A presentation by Peter Greenwood from the Australian Institution of Engineers, at the International Conference Supporting Small-and Medium-Sized Enterprises in Engineering and Technological Innovation Activity, Cracow, Poland. Hosted by WFEO-CET in cooperation with the Polish Federation of Engineering Associations.

[245] Mulder, K. (2008) Personal Communication with Dr Karel Mulder, Delft University of Technology, 28 August 2008.

[246] Sudan Virtual Engineering Library (SudVEL) (undated) website, www.sudvel-uofk.net/, accessed 25 October 2008. This Pilot Project was supported by UNESCO in partnership with the Foundation Ecole d'Ingenieurs EPF) through the International Institute of Women in Engineering (IIWE) Australian Virtual Engineering Library (AVEL-SKN) World Federation of Engineering Organizations (WFEO) Sustainable Alternatives Network (SANet) and the Natural Edge Project (TNEP).

[247] King, R. (2008) 'Addressing the Supply and Quality of Engineering Graduates for the New Century', Report to the Carrick Institute for Learning and Teaching in Higher Education Ltd, Sydney, pp63-64.

[248] Stern, N. (2006) *The Stern Review: The Economics of Climate Change*, Cambridge University Press, Cambridge.

[249] Beavis, C. (1997) 'Lovely Literature: Teacher Subjectivity and Curriculum Change', 1997 AARE Conference, The Australian Association for Research in Education, Brisbane.

[250] King, R. (2008) 'Addressing the Supply and Quality of Engineering Graduates for the New Century', Report to the Carrick Institute for Learning and Teaching in Higher Education Ltd, Sydney.

[251] Association for the Advancement of Sustainability in Higher Education (AASHE), 'Professional Development Opportunities', http://www.aashe.org/profdev/profdev.php, accessed 3 February 2010.

[252] Jorgensen, U. (2007) 'Historical Accounts of Engineering Education', in Crawley, E., Malmqvist, J., Ostlund, S., and Brodeur, D. (eds) *Rethinking Engineering Education: The CDIO Approach*, Springer Press, New York.

[253] Benyus, J. (1997) *Biomimicry: Innovation Inspired by Nature*, HarperCollins Publishers Inc., New York.

[254] Porrit, J. (2007) 'Short Interview at Global Sustainability Forum: The Future for Engineering Education', http://www3.imperial.ac.uk/globalsustainability, accessed 3 May 2008. Event

hosted by, at Imperial College's EnVision 2010 Initiative, Imperial College, London, 18 September 2007.

[255] These figures are not available in the literature, so are based on conversations with Engineers Australia and engineering educator colleagues in Australia and internationally, including heads of school and program convenors. Chapter 5 presents the peer review process which contributed to the formulation of these approximate timeframes.

[256] Desha, C. and Hargroves, K. (2007) 'Education for Sustainable Development Curriculum Audit (E4SD Audit): a curriculum diagnostic tool for quantifying requirements to embed sustainable development into higher education – demonstrated through a focus on engineering education', *World Transactions on Engineering and Technology Education*, vol 6, Issue 2.

[257] Desha, C., Hargroves, K. and Smith, M. (2009) 'Addressing the time lag dilemma in curriculum renewal towards engineering education for sustainable development', *International Journal of Sustainability in Higher Education*, vol 10, no 2, pp184-199.

[258] Holmberg, J., Svanström, M., Peet, D., Mulder, K., Ferrer-Balas, D. and Segalàs, J. (2008) 'Embedding Sustainability in Higher Education through Interaction with Lecturers: Case studies from three European Technical Universities', *European Journal of Engineering Education*, vol 33, no 3, pp271-282.

[259] The Alliance for Global Sustainability (2006) *The Observatory: Status of Engineering Education for Sustainable Development in European Higher Education*, EESD-Observatory, Technical University of Catalonia, Spain, p8, www.upc.edu./eesd-observatory/, accessed 17 July 2008.

[260] World Federation of Engineering Organsations (1997) 'Achievements - Educational Programs', www.wfeo.org/index.php?page=archives, accessed 2 March 2010.

[261] Desha, C., Hargroves, K. and Smith, M. (2009) 'Addressing the time lag dilemma in curriculum renewal towards engineering education for sustainable development', *International Journal of Sustainability in Higher Education*, vol 10, no 2, pp184-199.

[262] Soanes, C., and Hawker, S. (eds) (2005) *Compact Oxford English Dictionary of Current English,* 3rd Edition, Oxford University Press, 'rapid', http://www.askoxford.com/concise_oed/rapid?view=uk, 1 July 2009.

[263] Soanes, C., and Hawker, S. (eds) (2005) *Compact Oxford English Dictionary of Current English,* 3rd Edition, Oxford University Press, 'urgent', www.askoxford.com/concise_oed/urgent?view=uk, 1 July 2009.

[264] Soanes, C., and Hawker, S. (eds) (2005) *Compact Oxford English Dictionary of Current English*, 3rd Edition, Oxford University Press, 'challenging', www.askoxford.com/concise_oed/challenge?view=uk, 1 July 2009.

2. RESEARCH DESIGN

In this chapter the qualitative mixed-method research design to address the research problem is discussed. It comprises a somewhat unorthodox adaptive narrative approach to draw data from both the literature and personal experiences in the field. The chapter begins with a discussion of the research methodology which is particularly important given the historically relatively poor perception of qualitative research when compared with quantitative research as identified by researchers such as Patton.[1] The use of 'researcher as research instrument' is discussed including the use of the personal pronoun, demonstrating a meta-analytical awareness of being implicated in the process and method ramifications. The practice of using multiple-methods is then overviewed, with regard to triangulated data collection techniques that provide additional perspectives and confirmability.

2.1. Research methodology

2.1.1. Situating the research within a research paradigm

Broadly speaking, there appear to be two major theoretical paradigms (or 'perspectives') which underpin the nature of sociological research; the *quantitative* paradigm and the *qualitative* paradigm.[2,3] Researchers also refer to these paradigms using terms such as positivist, traditional, experimental, or empiricist for the quantitative approach, and phenomenological, naturalistic, interpretive, post-positivist or post-modern for the qualitative approach.[4,5] The quantitative paradigm can be traced back to theorists in the 19th and early 20th Centuries, in particular to scholars such as Comte and Durkheim. Authors Smith[6] and later Creswell,[7] explain that the field of 'Qualitative Research', or 'Qualitative Inquiry' began as a countermovement to the positivist tradition in the mid-late 20th Century. This was led by writers such as Dilthey, Weber, and Kant, in response to a growing body of interdisciplinary research needs such as education, social work, information studies, management, and women's studies. Wolcock[8] suggests that the common roots of qualitative inquiry can be found in three major data-gathering techniques basic to everyday life: 1) experiencing (particularly watching and listening), 2) enquiring (where the researcher's role becomes more intrusive than an observer), and 3) examining (where the researcher makes use of materials prepared by others). Pitman and Maxwell[9] comment that qualitative analysis benefits from its, '*flexibility rather than standardization, understanding rather than generalizability, and a commitment to many valid perspectives rather than a single truth*'.

Creswell summarises the assumptions within each of these paradigms as shown in Table 2-1. Essentially a quantitative 'positivist' approach is concerned with the facts or causes of social phenomena, separating them from the perspectives of the individuals concerned. Positivist researchers adopt a 'natural sciences' model of research, searching for causes through methods such as questionnaires, inventories, demography, producing data suitable for statistical analysis. In contrast, a qualitative 'constructivist' approach is concerned with understanding or interpreting social phenomena from the individual (personal) perspective, and reality through perception and experience, drawing from the fields of philosophy and sociology using methods such as participant observation, in-depth interviews, and narrative inquiry. Qualitative research results in descriptive data sets for analysis.

Table 2-1. Quantitative and qualitative paradigm assumptions

Assumption	Question	Quantitative Paradigm	Qualitative Paradigm
Ontological	*What is the nature of reality?*	Objective and singular, apart from the researcher	Subjective and multiple (as seen by study participants)
Epistemological	*What is the view of knowledge?*	Prepositional knowledge (singular) which is to be found, independent of the researcher	Prepositional knowledge (multiple) which exist only when attached to the researcher
Axiological	*What is the role of values?*	Value-free and unbiased; researcher is independent from that being researched	Value-laden and biased; researcher interacts with that being researched
Rhetorical	*What is the language of research?*	Formal, based on set definitions, with impersonal voice and use of accepted quantitative vocabulary	Informal, evolving decisions, personal voice, using accepted qualitative vocabulary
Methodological	*What is the process of research?*	Deductive, cause and effect, static design and context free, with generalisations leading to prediction, explanation and understanding. Accurate, valid and reliable	Inductive, mutual simultaneous shaping of factors, emerging design and context bound, patterns and theories developed for understanding. Reliable and confirmable

Source: Adapted from Creswell (1994)[10], based on Firestone (1997),[11] Guba and Lincoln (1988),[12] and McCracken (1988)[13]

In describing these two paradigms, Creswell notes that quantitative research may include qualitative methods; that is, research problems may not necessarily be

definitively quantitative or qualitative.[14] Patton asserts that there is value in having different mixes of designs, data and analyses, which include using experimental and quantitative methods in combination with qualitative ones.[15] Indeed, Guba and Lincoln note that these paradigms are beginning to 'interbreed' such that research can now contain both methodologies, representing the best of both world-views.[16]

Susman and Evered[17] apply a cautious approach to applying quantitative 'positivist' principles to studies involving human behaviour, pointing out a particular challenge with regard to the need to consider the effects of intruding values. Denscombe reflects that using a mixed method approach to research can assist by providing a pragmatic philosophical foundation where the researcher treats the research problem, and answers to the research problem, as the overriding concern,[18] and where any method that produces findings of practical value to address the problem should be considered.

It is hence clear from the literature that it is preferable to situate a research problem wholly or largely within one of the two major paradigms, to minimise the potential for confusion and lack of rigour or confirmability in addressing the assumptions in Table 2-1. However, there is a growing acceptance that research may incorporate some elements of either paradigms (for example being qualitative with some quantitative elements), bringing together methods previously regarded as incompatible. Furthermore, the use of multiple methods within either paradigm can be helpful in demonstrating objectivity and reliability (in quantitative research) or confirmability and credibility (in qualitative research). Table 2-2summarises the nature of this dissertation based on the headings in Table 2-1, demonstrating that the research is situated within the qualitative paradigm, incorporating a few important considerations from the quantitative paradigm.

Table 2-2. Summary of the research approach with regard to research paradigms

Consideration	Paradigm assumption
Ontology	– Subjective and multiple perspectives evident, as seen by engineering professionals considering the role of engineering in sustainable development, educators documenting perspectives on curriculum and curriculum renewal, and personal reflection on previous experiences. – Objective singular perspectives evident in inquiring about challenges and the state of engineering education for sustainable development (summarising scientific studies and surveys).
Epistemology	– Largely comprises a qualitative approach, where the researcher's reality influences the type of knowledge subjectively sought and recognised. – The researcher systematically but subjectively enquires about curriculum renewal in the literature, and through reflection on previous experiences.

Consideration	Paradigm assumption
Axiology	Value-laden and biased towards prior experiences and perspective: – Largely phenomenological in approach, attempting to understand appropriate contexts for using identified mechanisms, using a reflective inquiry into personal experiences and iterative formal peer review. – Project experiences as a researcher and lecturer involve interaction with other researchers – researcher implicated in problem being researched.
Rhetoric	– Involves relatively informal and preliminary descriptions of concepts, drawing on accepted qualitative vocabulary to introduce new terms. – A significant proportion of the study method involves the use of personal voice, through self reflection on previous project experiences.
Methodology	– Literature review methods are deductive, consider cause and effect, and generate generalisations to explain and understand the context. Information considered reliable through using multiple sources and perspectives to seek confirmability. – Inductive processes used to find patterns of rapid curriculum renewal in the literature and in personal experiences, if they exist, developing an emerging design that is context bound, and seeking a model to understand the process of rapid curriculum renewal.

2.1.2. Defining the research approach

The methods available to investigate the research problem will be influenced largely by how the research question is positioned; i.e. the research approach. This may range from highly objective, theoretical examination of key concepts, through to a more subjective perspective, using common-sense theories and everyday knowledge to examine the literature about what is occurring.

For example, an 'armchair theorist'[19] research approach might begin with a situational analysis of what is happening to engineering education and why, and a body of literature would be examined for what it might suggest as important elements for reconsideration in curriculum construction, resulting in a conceptually based, theorised 'philosophical dissertation'. However, this approach carries a risk of theory overwhelming all other considerations, resulting in 'theoretical arrogance', or 'hubris'. Alternatively, a 'field based research'[20] approach might comprise considering past and current action within the professional community and indicate emerging professional needs that potentially should be captured in the curriculum reconstruction process. Such a dissertation may then involve the researcher reflecting on how this curriculum renewal process might be conceptualised and implemented using literature and personal experiences, given the identified challenges and rigidities that have been there in the past.

UK social researcher Derek Layder discusses a growing gap between the armchair (i.e. 'general theory') and field based (i.e. 'applied social research') approaches, noting that,

> *"… many social researchers often experience a lack of guidance as to how to deal with theory, how to use it and how to develop it from the data they unearth during their research … the gap between general social theory and 'empirical' theories (associated with the analysis and explanation of empirical data, information and findings) should be closed down in order to harness the potentially productive interplay between them."*[21]

Layder offers a new middle-spectrum approach in the form of 'adaptive theory' which can be used to generate new theory as well as develop existing theory in conjunction with empirical research, whereby the theory both *adapts to* (i.e. is shaped by) incoming evidence while at the same time data are filtered through the theoretical perspective. Data are therefore adapted by the theoretical materials (i.e. models, concepts, ideas) that are relevant to their analysis.[22] In this way, adaptive theory aligns with inductive research which is inherent in the qualitative paradigm discussed earlier. Layder proposes that the increased adequacy and validity of knowledge provided by adaptive research is reflected in enhanced and more accurate renderings of particular phenomena (groups, milieu, or social problems) under study, in addition to a drive to develop more powerful explanations.[23]

While early writers in the field of sociology such as Durkheim developed theoretical and conceptual models alongside empirical inquiry to better understand society as a whole, recent social analysts including Layder prefer to avoid such 'meta-narratives'. For example, Layder concludes that while the theory may be made more robust and assisted by having assumptions, axioms and presumptions closely and routinely measured against empirical evidence, empirical research can benefit from more sophisticated forms of analysis, in addition to having enhanced generalisability and applicability.[24] His 'adaptive theory' proposes that greater adequacy and credibility should be understood as the best approximation to 'truth' given the present state of knowledge and understanding, simply representing the 'latest stage' in the elaboration of a given theory, which can be later revised with findings from future research and theoretical developments; in effect an *'interim way-station which is potentially revisable and reformulable'*.[25]

Given these considerations, it is concluded that this dissertation uses an adaptive approach to considering the research problem. Within this approach, the 'armchair' dimension is evident in ascertaining the state of education for sustainable development

and elements of rapid curriculum renewal through contextual and integrative literature reviews. The 'field-based' dimension is evident in a phenomenological approach that places particular emphasis on the individual's view, where personal involvement in projects provides insights that further inform the investigation.

2.1.3. Using multiple and iterative methods

Qualitative research is inherently multi-method in focus, whereby the use of multiple methods, or triangulation, seeks to develop an in-depth understanding of the phenomenon in question, providing a valuable alternative to the method of 'validation' used in quantitative research.[26] This is particularly important where the researcher is intimately and subjectively implicated throughout the research process, as the methodology needs to convince other researchers that the findings have been viewed with sufficient scrutiny to warrant the outcomes.

Researchers Rocco *et al*[27] explain in the *Handbook of Mixed Methods in Social and Behavioural Research*,[28] that consciously going back and forth between various qualitative interpretations and analyses can yield important insights concerning the phenomena under study using a variety of empirical materials. Maxwell and Loomis also discuss in the handbook, the 'interactive' networked nature of such dialectical research, where the integration of multiple perspectives is seen as being better able to reflect social realities.[29] Researchers Greene and Caracelli agree, concluding that the underlying rationale for mixed-method inquiry is to understand more fully, generating insights that are deeper and more broad, and developing important new knowledge that respects a wider range of interests and perspectives.[30] Fink explains that this deployment of a wide range of interconnected interpretive practices is undertaken in the hope of getting a better understanding of the subject matter at hand, understanding that each practice will make the world visible in a different way.[31]

In their publication *The Landscape of Qualitative Research*, Denzin and Lincoln explain that a multiple-method approach within qualitative research can take advantage of the benefits of a number of methods available that describe routine and problematic moments and meanings in individual's lives.[32] This includes for example case study, personal experience, introspection, life story, interview, artefacts, cultural texts and productions, observational, historical, interactional, and visual texts. However, Morse cautions that using a mixed methods approach can also be seen as a weakness as it could potentially be considered less rigorous.[33] Hence, the selection of methods that complement and strengthen the research methodology is crucial to obtaining findings that are credible.

2.1.4. Using self as an instrument

Within the phenomenological research methodology – in particular within education research – various forms of narrative research (i.e. investigation into personal experiences) are increasingly being used by qualitative researchers to include personal experience as a credible and confirmable source of information within an investigation. Denzin and Lincoln refer to the 'bricoleur' researcher, who is adept at performing a large range of research tasks, from interviewing to intensive self-reflection and introspection, where, *'the researcher-as-bricoleur-theorist works within and between competing and overlapping perspectives'*.[34]

Such contemporary influences are evident in this study, which has also drawn on methods used by other researchers in the field, in particular other studies that included unconventional personal narrative approaches within their methodology. For example, Davis[35] adopted a personal narrative approach, including journaling, which reflected her research journey based on the development of a curriculum innovation in environmental education. Godfrey[36] used predominantly ethnographic methods of data collection in exploring the culture of engineering education and its interaction with gender, through a case study of an engineering department in her university. Mutch[37] used an unconventional approach in her dissertation investigation of context, complexity and contestation issues within New Zealand curriculum including liberties with the layout of the dissertation and multiple-layered story-telling to, *'open up the complications that* [would] *otherwise have been smoothed over'*.[38] The previously mentioned authors also used alternative layouts for their dissertations, arising from their qualitative, non-traditional methodologies.

The use of personal experiences – and the personal pronoun 'I' – to create a significant source of information is not a new concept. For example, in his seminal 1959 publication *Sociological Imagination*, Wright Mills provided the following advice for social researchers:

> *'You must learn to use your life experiences in your intellectual work: continually to examine and interpret it. In this sense craftsmanship is the centre of yourself and you are personally involved in every intellectual product upon which you may work.'*[39]

Pinar wrote about formal reflection in 1972, formulating the term 'currere' which refers to, *'an existential experience of institutional structures'* and where the method is a strategy for self-reflection that enables the researcher to encounter an experience more fully and more clearly.[40] According to Riessman[41] more than three decades later, the

analysis of personal narrative has undergone a wellspring of interest, from anthropology and folklore to psychology, sociolinguistics and sociology.

Within this emerging field of inquiry, there are a number of terms used to describe the narrative process, including personal narrative,[42] portraiture,[43] auto-biographical narrative,[44] interpretive phenomenological analysis,[45] and auto-ethnographic critical narrative[46] or reflexive inquiry.[47] Of these options, auto-ethnographic reflexive inquiry is considered the most appropriate for this investigation. This could be said to align with a feminist social research approach, as discussed by Neuman, where characteristics include flexibility in: choosing research techniques and crossing boundaries between academic fields; incorporating the researcher's personal feelings and experiences into the research process; and action-oriented research that seeks to facilitate personal and societal change.[48] Moreover, as Mishler[49] suggests, this approach could be seen as a form of 'case-centred research', which takes as its object of investigation the story itself. Laslett summarises the field well by concluding that analysing personal narratives can illuminate individual and collective action and meanings, as well as change processes.[50]

2.1.5. Methodology summary

In summary, given the flexibility in method permitted by researchers such as Denscombe,[51] Layder,[52] and Denzin and Lincoln,[53] this research adopts a slightly unorthodox mixed-method[54] through an adaptive and interpretive approach that is situated within a qualitative research paradigm. The research design is iterative and involves multiple methods, drawing from the perspectives of both the 'armchair theorist' and field-based researcher. This approach fits in well with Layder's continual refinement perspective on qualitative research, where he explains that the purpose of social inquiry is to produce ever more adequate knowledge to produce more robust conclusions. Johnson and Casey discuss the notion of 'problematic' in narrative research, which is inherently internally complex and recognises that problems are never really 'solved'.[55] Rather, elements taken from existing problematics can, when reorganised and examined in a new order, result in much greater clarity and understanding. It is considered that the use of multiple methods can contribute to producing such enhanced clarity with regard to the nature of the problem, the state of engineering education for sustainable development, and mechanisms to address time-constrained curriculum renewal.

This study uses three main sources of data: literature from authors describing experiences and evolving theories; personal narrative of the researcher's previous

project experiences; and peer review from experts in the field regarding the findings from those experiences. Historical and ethnographic research methods are used through *literature review*, and *reflexive inquiry* (i.e. personal review) to undertake document analysis and archival research using content and thematic analysis, followed by *peer review* to triangulate data sources.

The proposed method to address the research question is summarised diagrammatically in Figure 2-1, within the context of the dissertation chapters. An intepretivist's view of the following three questions figures prominently, embedded in the dissertation process itself as noted here:

1. What are we seeing here in curriculum? *This is addressed through the three processes of literature review, reflexive inquiry and peer review.*
2. Why is this so? *This is addressed through interpretive analysis, using data gathered from the three processes.*
3. What if anything, should we be doing about it? *This is addressed through the development of a model and subsequent propositions.*

Rather than the conventional scientific format of separate chapters for literature review followed by a chapter on research 'findings', the layout of the dissertation highlights the interdependence of the methods and findings, expressed through the sequencing of literature review, followed by narrative inquiry, peer review and the subsequent emerging model for rapid curriculum renewal. It also provides transparency regarding how the researcher's values and perspectives have changed through the dissertation, through the use of a prelude and postscript which 'bookend' the dissertation and provide a lens through which the approach and role of the researcher can be viewed.

Each of the three methods is discussed in the following section, noting where they build on, reinforce and complement other methods and findings within the research design.

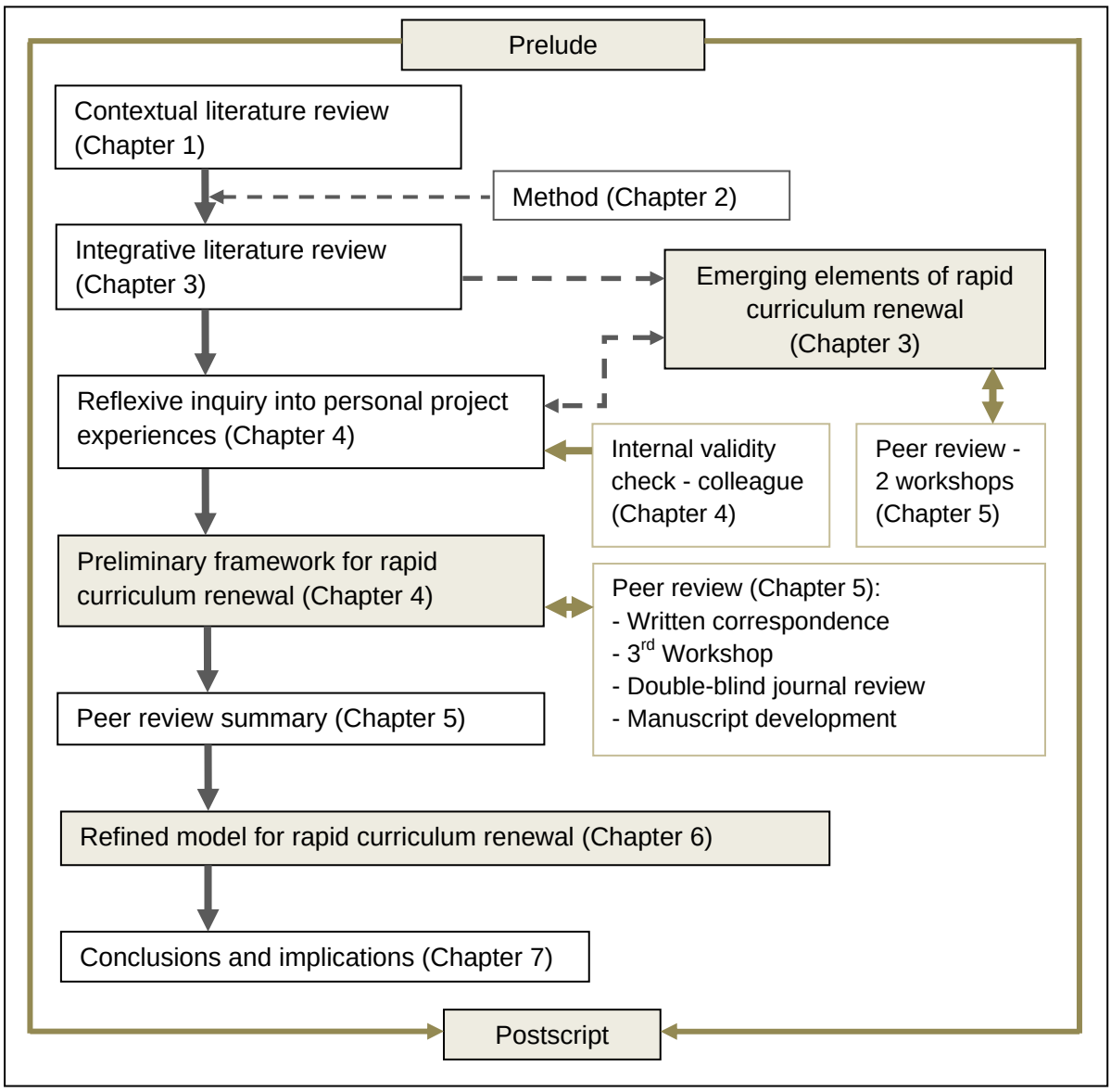

Figure 2-1. Stylistic representation of the multiple-method, iterative methodology

2.2. Research methods

In contrast to a traditional scientific mode of enquiry which results in a dissertation that approaches a well validated explanation of what would happen in a similar circumstance in the future, the thesis of interpretive research comprises a theorisation of propositional knowledge, modelled according to the perspective of the researcher. In this case three different methods are used to generate the propositional knowledge; namely literature review, reflexive review of personal experiences, and peer review. These methods try to address what positivists would call the 'validity of the study', which qualitative researchers call the 'confirmability' or 'credibility' of the study, creating the necessary distance between the researcher and the outcomes of the research as described in the following paragraphs.

2.2.1. Literature Review

2.2.1.1. Contextual literature review

In conducting a literature review, the researcher assumes that knowledge accumulates and that future research can build on what has been done previously.[56] The most common reason for undertaking a review of literature is to create links to a developing body of knowledge, commonly referred to as a 'literature review', or a 'background' or 'context' review.[57] Neuman summarises four key goals for a literature review, including: 1) to demonstrate familiarity with a body of knowledge; 2) to highlight the path of prior research on the topic; 3) to summarise what is known about the topic; and 4) to learn from other researchers, stimulating ideas for further research.[58]

This dissertation includes a contextual literature review, as presented in Chapter 1, to discuss the problem context, to derive the research question, and to establish its significance. Specifically, the review investigated emerging 21st Century challenges with regard to sustainable development and roles for the professions, the key role of the engineering profession, and the urgent need for engineering education for sustainable development. The questions asked within the contextual literature review included:

- What is written about challenges facing contemporary society?
- Are there links being made between societal challenges and the role of education? Within this context, what is written about the changing role of education?
- What is being discussed about the role of engineering and capacity building? Is there evidence of change within engineering curriculum, to address the profession's

capacity to assist with emerging challenges?

The contextual review of literature therefore encompasses two significant bodies of literature to address these questions:

– Literature concerning challenges facing society in the 21st Century and the need for competent professionals to help address them. In particular, literature discussing the role of the engineering profession. This literature has been reviewed to help define the nature of the problem.

– Literature concerning engineering education with regard to the extent and timing of its response (i.e. how far and how fast) to such challenges involving new knowledge and skills such as sustainable development. This literature has been reviewed to help define the nature of the problem, and is also a primary source of information to investigate opportunities for addressing the problem as it affects the engineering discipline.

2.2.1.2. Integrative literature review

As stated earlier, a second reason for undertaking a literature review is to be able to effectively represent the state of current research, summarising past research and then drawing overall conclusions from many studies.[59] This is referred to as an 'integrative' review of the literature, which allows for exploring which research methods have been used successfully, evaluating the strength of scientific evidence, identifying gaps in current research, the need for future research, building bridges between related areas of work, identifying central issues in an area, and generating a new research question or questions emerging in the field. It may also be used to identify a theoretical or conceptual model.[60] The four questions asked in an integrative review process are: 1) What is known?; 2) What is the quality of what is known?; 3) What should be known?; and 4) What is the next step for research or practice?[61]

This dissertation includes an integrative literature review, as presented in Chapter 3, to examine the field of curriculum renewal literature, summarising what is known at this point in time about the process of curriculum renewal theory and the emerging concept of rapid curriculum renewal. Further to the contextual literature review, this integrative review asks what is evident in the literature regarding time-constrained curriculum renewal, assuming that there may be a different model of curriculum development or design in times of urgency, as opposed to ordinary or stable times.

To answer this question, the review begins by identifying the existing elements of curriculum renewal. This then forms the basis for considering the notion of curriculum

renewal in urgent times, and the potential for the elements to be different in such circumstances, methodologically linking the themes that are essential for the focus in this study. The questions asked within the integrative review are:

– In the literature, is it assumed that the process of curriculum renewal remains constant under any circumstances (It may be that the review finds nothing new about the elements of rapid curriculum renewal, other than the models produced by numerous theorists)?

– If this is the case, are there examples of curriculum renewal under urgent and challenging circumstances which contradict this assumption (this can then be investigated for variations to the method of curriculum renewal)? If this is not the case, then what additional elements are suggested for addressing curriculum renewal in urgent and challenging times?

– From the literature review, can a preliminary set of 'elements of rapid curriculum renewal' be distilled, which could be used to guide curriculum renewal in urgent and challenging times?

The integrative review therefore encompasses two significant bodies of literature associated with the disciplinary field:

– Literature concerning curriculum renewal with regard to how higher education curriculum is modified (or 'renewed') to embed new knowledge and skills in programs, including literature on the timely integration of new knowledge and skills. This body of literature is a primary source of information to investigate opportunities for addressing the problem.

– Literature concerning higher education experiences in undertaking rapid curriculum renewal, in Australia and overseas. This body of literature is used to cross-check and add to findings from the curriculum renewal theory literature.

2.2.2. Reflexive inquiry

2.2.2.1. Personal narrative

Reflexive inquiry places the self within a social context, encouraging the exploration of ways in which a researcher's involvement with a particular study influences, acts upon and informs such research.[62] There is a self-conscious injection of the person into the process, recognising explicitly that this is what is being done. Essentially the approach allows the researcher to be both dispassionate, and a participant implicated in the work.

The review of personal experiences was guided by a number of pre-determined questions that align with the personal narrative approach described earlier:

1. What did my project experience comprise, relating to emerging elements of rapid curriculum renewal evident in the literature?
2. What did I learn from my experiences in this project, compared with the literature?
3. How could I apply learning from this experience the elements of rapid curriculum renewal emerging from the literature?

Reflexive inquiry also requires researchers to create a data-set for systematic examination, involving multiple information sources to improve confirmability and to reduce the potential for bias in gathering data. Sources of information in this study include personal journals from work during projects, project reports, a write-up of reflections on these personal project journals, and formal review of these summaries by a project partner who was involved in the study from a collaborating institution. Each of the documents gathered for use in the analysis is ascribed a title for ease of reference, and all documentation remains confidential, filed securely as a key requirement of the personal reflexive process.

2.2.2.2. Prelude and Postscript

Nightingale and Cromby explain that reflexivity requires an awareness of the researcher's contribution to the construction of meanings throughout the research process, in addition to an acknowledgment of the impossibility of remaining 'outside of' one's subject matter while conducting research. In this way, reflexivity helps the researcher to explore ways in which his or her involvement with particular experiences influences, acts upon and informs the research being undertaken.[63] Hence, this study's methodology includes a declarative piece at the beginning of the dissertation (i.e. a 'Prelude') to show the positions brought into the research, including a number of strongly held perspectives contribute to the basis of the research question.

Given the role of the researcher as a research instrument in narrative inquiry, it is important to reflect on how he or she may have changed perspective and altered values on some of the aspects of the study. Hence, at the conclusion of the dissertation further personal reflection is also presented (i.e. a Postscript), to show how the conditions of thinking and the positions taken into the study, have been subject to some refinement and further development, resulting in enhanced awareness about challenges and opportunities in the future. This provides further evidence of the study as interpretive methods in action.

2.2.3. Peer review

Lincoln and Guba describe peer review or debriefing as the review of data and research processes by someone who is familiar with the research or the phenomenon being explored; providing support, playing devil's advocate, and challenging the researchers' assumptions to push the research to the next step methodologically - in other words, asking the hard questions about methods and interpretations.[64] Creswell and Miller highlight the routine use of methods such as triangulation and peer reviews (or 'peer debriefing') in qualitative research.[65] This supports the axiological assumption of the qualitative paradigm discussed earlier, which is to improve understanding by minimising the distance between the researcher and the informant.[66] Furthermore, in considering a phenomenological approach to research, Creswell cites Dukes[67] who suggests that while the steps for data analysis are less structured and more open to alternative procedures, the researcher should, *"look for 'structural invariants' of a particular type of experience – the patterns – and then submit these patterns to a different researcher for confirmation*."[68]

When using peer review input, Creswell and Miller suggest that credibility is enhanced through peer review when the reviewers are external to the study. They also suggest that the procedure is best used over time, during the process of the entire study, where peers provide written or verbal feedback to researchers, or serve as a sounding board for ideas.[69] Shashok notes that care should be taken with drawing conclusions due to factors, including:[70]

- peer reviewers are assumed to be experts in the field whose feedback on the content will be a reliable reflection of the field. In reality this depends on the selection process for the reviewers, and understanding limitations of the feedback received.
- peer reviewers are presumed not to have any 'formal relationship' with the person seeking peer review which might influence the level of critique. In reality, particularly in an emerging field, the pool of potential reviewers on a given topic area is small, and they are likely to know the authors of the work.
- peer reviewers are presumed not to be affected by biases and values which are counter-productive to the review process. In reality private and work circumstances mean that all reviewers might influence their perspective and subsequently comments provided in the review process.

Despite these potential issues, it was concluded that peer review is a useful method, in an inductive interpretive approach to iteratively seek formal review regarding the

preliminary findings from a broad cross-section of researchers, practitioners and students internationally. Notwithstanding that the sample might be biased towards the researcher's appreciation of the field and therefore not statistically representative, the process of peer review would help to ensure that the findings are sufficiently pragmatic and realistic with regard to the scale of the challenges, and the existing inertia within the higher education sector, in particular in engineering education. Hence, the research design includes checks for credibility of the data using peer review, as follows.

Firstly, the reflexive inquiry process includes review by a colleague involved in the majority of projects, to cross-check for internal confirmability and to further inform the findings. The peer review considers the following two questions: 1) *How could this be improved to provide an accurate description of what happened in this project?*; and 2) *Is there anything that could be added with respect to these documented learnings?* The results of this review are incorporated into the discussion in Chapter 4.

Secondly, to ensure that documented learnings from prior project experiences would be transferable to other engineering educators, formal peer review of the preliminary findings is sought from engineering educators in Australia and oversees, to suggest improvements to the emerging model for addressing the issue. Three mechanisms are used within the peer review process to check for credibility and confirmability:

1. *Face-to-face peer-review:* to review the preliminary set of elements by engineering educators in the field through workshops, as part of several conferences.
2. *Written open peer-review:* to seek feedback on an emerging model of rapid curriculum renewal, comprising papers describing various elements and their function, involving more than 40 engineering educators internationally.
3. *Written anonymous peer-review:* (i.e. double blind review) to seek feedback on a refined model, through a number of papers drafted for journal publication.

The findings of the peer review process are described in Chapter 5, continuing the style of reflexive inquiry used in Chapter 4. This includes findings from the peer review of emerging elements, and the subsequent peer review process for a proposed model of rapid curriculum renewal. Publications arising from the peer review that are directly related to this thesis are attached in Appendix A.

2.3. Reliability and validity

Qualitative research is commonly challenged when addressing trustworthiness transferability concerns beyond the research - in this case the applicability of a model for rapid curriculum renewal to engineering educators in Australia and overseas. Robson[71] refers to methods of establishing trustworthiness that include reliability and objectivity (i.e. credibility), and internal and external validity (i.e. confirmability). Leal Fihlo[72] also discusses the use of such methods in sustainability research in higher education, commenting that it is important to triangulate or find convergence among sources of information, different investigators, and different methods of data collection.

In summary, credibility describes the consistency of measurement, or the 'repeatability' of the measurement, including inter-observer, test-retest, parallel-forms, and internal consistency reliability.[73] Although the analysis comprises historical data (i.e. past experiences documented in the literature and in a personal narrative), the issue of inter-observer reliability/ credibility is pertinent to this research, in considering how to interpret the presence or lack of relevant information in the literature and personal experiences. Hence, formal peer review processes are included in the research design, to enable feedback to be provided about the credibility of the literature reviews an personal reflections. In addition, contact is also made with authors of a number of papers, to clarify that the researcher's interpretations fairly represent what occurred.

Confirmability relates to the strength of inferences or propositions made, and the conclusions of the study.[74] External confirmability - the extent to which the results of this study can be generalised to other settings - is considered to be a key consideration for this research design, given the desire to create a model which could be used anywhere in engineering education institutions. Hence, multiple methods are incorporated, including external peer review to ensure that the findings resonate with engineering educators at other universities in Australia and overseas. Internal confirmability is also considered important in the research design, in particular the potential for limited literature review, case studies and personal experiences to compromise the integrity of the results. Therefore other discipline case studies and multiple personal experiences are included to support the literature review findings. As shown in Figure 2-2, the use of multiple methods in this study reflects an attempt to secure an in-depth understanding of the phenomenon in question through triangulation,[75] which also improves the confirmability of the findings.

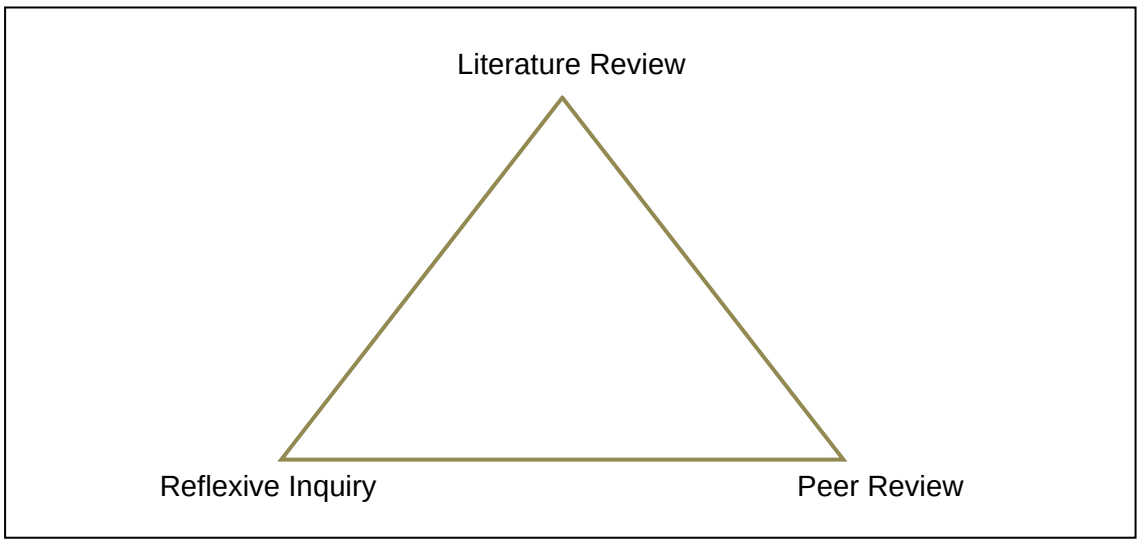

Figure 2-2. Stylistic representation showing the triangulation of multiple methods

In the *Sage Dictionary of Social Research Methods*, researcher Reed-Danahay reflects that being aware of one's position in the context of research (rather than denying it), is not at odds with forms of 'truth' or 'validity'; this form of research can be critically evaluated with regard to how well it synthesizes the subjective experience of the participant and the structural conditions in which their experiences take place.[76] However, researchers Bullough and Pinnegar comment that such 'self-study' is an area of research in teacher education that is in its infancy. Hence, in self-studies, *'conclusions are hard won, elusive, are generally more tentative than not. The aim of self-study research is to provoke, challenge, and illuminate rather than confirm and settle'*.[77] With such considerations in mind, Denscombe cautions that the narrative task is to present the experiences in a way that is faithful to the original.[78]

In considering such needs for ensuring validity and reliability of the information, the following four potential issues highlighted by Neuman have been addressed in the research design:[79]

1. *Overgeneralisation - where a particular set of evidence is assumed to apply to many other situations:* This is minimised through reliance on an extensive literature review and triangulation with personal experiences in the engineering education field, and where generalisations are made (for example with regard to national and international contexts, and application for other disciplines), the limitations are clearly acknowledged.

2. *Selective Observation - where the researcher may take special notice of some people or events and use this as a basis for generalising about a larger population*

or set of circumstances (i.e. 'over-interpreting'): The potential error in seeking out evidence that confirms what is already known is avoided through peer review of the findings, ensuring that different perspectives on the data are acknowledged.

3. *Premature closure - where the researcher feels he or she has all of the answers and do not need to listen, seek information, or raise questions any longer*: This potential for 'jumping to conclusions' is minimised through triangulation of the literature review, reflective analysis and the use of extensive peer-review, resulting in iterative considerations of information.

4. *Halo Effect - where the researcher gives organisations, events or people who are respected strong representation, or a 'halo', rather than considering them on their research merit alone*: The potential for individual reflections to affect a model of elements for curriculum renewal is minimised through the use of wide-reaching peer review, including engineering educators in Australia and overseas.

Riessman also discusses the wide variability in how investigators undertake personal narrative investigations, and in the methodological assumptions and analysis strategies which are usually discipline related. Casey concurs, concluding *'whether implicit or elaborated, every study of narrative is based on a particular understanding of the speaker's self'*.[80] To address the potential for personal perspective to adversely affect the credibility of the results, the investigation addresses the basic understandings summarised in Table 2-3.

Table 2-3. Method considerations to enhance confirmability

Assumption	Question
The narration is distinguished by ordering and sequence. Temporal ordering of a plot is most familiar, but may also be organised thematically and episodically (Gee,[81] Michaels,[82] and Riessman[83])	The narration of personal experiences is separated into experiences as an educator, and experiences as a researcher. Within each of these themes, the narration is chronological, which is advantageous in permitting reflection on what was learned through progressive project experiences.
The narrator creates plots from disordered experiences:[84]	The process of reflexive inquiry allows a systematic consideration of otherwise *ad hoc* experiences in curriculum renewal.
Narrators structure their tales temporally and spatially, recounting experiences that are located in particular times and places:[85]	The accounts of previous project experiences all include introductions to orient the reflection, describing the time and place of the experience.
Narrators use particular linguistic devices to hold their accounts together and communicate meaning to listeners:	The narration in this dissertation uses the personal pronoun to communicate experiences and key learnings, keeping the reflection focused on one perspective and assisting readability.
Human agency and imagination are vividly expressed, *creating themes and making sense of themselves, social situations, and history:*[86]	The narration focuses on distilling learnings about key themes, or elements, of rapid curriculum renewal from each account, also drawing on the established themes from the literature review process.

Bullough and Pinnegar also provide a list of guidelines for conducting reflexive inquiry, most of which have been discussed in the above paragraphs, however, two additional considerations are noted here:[87]

- To be seen as scholarship, edited conversation or correspondence must not only have coherence and structure, but that coherence and structure should provide argumentation and convincing evidence: In Chapter 5, direct references to documentation and communications are only included where their inclusion enhances understanding of the topic being discussed.
- *Interpretations made of self-study data should not only reveal but also interrogate the relationships, contradictions, and limits of the views presented:* In Chapter 5, when discussing each project experience, care is taken to consider the context of the project and any associated limitations in drawing conclusions from the experience.

2.4. Ethical issues and considerations

Robson[88] notes a distinction between ethics and morals, where ethics are usually taken as referring to general principles of what one ought to do, while morals are usually taken as concerned with whether or not a specific act is consistent with the accepted notions of right or wrong. With the approach to the research problem outlined earlier, the Griffith University Office of Research online ethics checking system was used to determine the extent of approvals required to undertake this research.

Subsequently, no ethics clearance was deemed necessary for the literature review and personal reflexive inquiry process involving the researcher only. Furthermore, previous projects and conference-based workshops referred to in Chapter 4 which involved participants were undertaken with the usual ethics considerations (including voluntary and confidential participation, and informed consent for use in future dissertation, journal and text book publications) and E2 approvals from Griffith University's Office for various research initiatives.

Hence, the only area of the research requiring ethics consideration for this dissertation is the peer review of the reflexive inquiry process referred to in Chapter 4. Ethical clearance was therefore obtained from Griffith University[89] for this aspect of the research (E2, ENG/03/09/HREC, see Appendix B).

With regard to ethics considerations throughout the dissertation, ethical issues addressed within this methodology include:

– *The potential for individuals providing input to, or feedback on, any aspect of the dissertation, including the personal reflections, survey and formal peer review, to be recognised in the dissertation:* This is addressed by ensuring that any reference to institution or individual in the dissertation is agreed to by the individual. Any quotes directly attributable to individuals are checked with the individual prior to inclusion.

– *The potential for participants in any aspect of the research to be adversely affected in their workplace, resulting from their contribution to the research:* This is addressed by ensuring that all interactions are confidential unless public disclosure is requested prior to the research, or unless express permission is sought from the participant to be acknowledged.

2.5. Limitations of the research

The iterative and triangulated method is intended to deliver a level of rigour where others may draw similar conclusions by reading and reviewing the literature reviews, reflexive inquiry and peer review process. Furthermore, the method is intended to provide a robust basis for future critical review of the model. However, the following points are made with regard to research limitations for this dissertation:

- *Limits of methodology and techniques*: The research methodology and techniques are centred around the interpretation and analysis of data from existing examples in engineering education and other disciplines within higher education. This may be vulnerable to inaccuracies or biased to particular events specific to the examples examined, rather than global engineering education. Furthermore, the methodology uses a number of methods, each of which may also have relied upon assumptions which may incorporate an element of error.
- *Time and resource constraints*: affecting the peer review process, in particular with regard to seeking pro-bono peer review from academics who have busy schedules, including large teaching workloads. Future research may address this issue through making resources and thus time available (e.g. through honorariums).
- *Defined limits of research*: The limits of the research are defined to information sourced from engineering education and other selected discipline areas. However, documented studies by others is not always complete or rigorous. For example, a researcher describing a particular curriculum practice may be the sole author and if they stop teaching, the practice ceases. In such circumstances there is a problem with whether the practicalities can ever really be known. With this in mind, it is highlighted that this dissertation references research by authors which may have been only partially evaluated.
- *Generality of research findings*: The research investigates information relevant to engineering education in the higher education sector, and applies findings to developing a model for engineering education for sustainable development. Within the chapters, the discussion includes explicit commentary about assumptions made and limitations of the methods used for qualitative analysis.
- *Isolation of research findings*: The research findings are intended to apply to curriculum renewal in engineering education. There may be opportunities to extrapolate findings to other discipline areas within higher education as noted in the final chapter, however, this is beyond the scope of this investigation.

2.6. Conclusion

In this study, a somewhat unorthodox mixed-method approach is used, situated within a qualitative research paradigm. The dissertation crosses between the fields of sustainable development science, engineering education and curriculum renewal processes, and is a narrative interpretive research process that seeks to facilitate personal and societal change.

The research design is iterative and involves multiple methods, drawing from the perspectives of both an 'armchair theorist' and field-based researcher, where the armchair theorist's perspective is evident in the contextual and integrative literature reviews to ascertain the state of education for sustainable development and elements of rapid curriculum renewal; and the field-based research perspective is evident in the phenomenological approach that places particular emphasis on the individual's view, where there is a personal commitment to and involvement in projects that provide insights and potential learning. A prelude and postscript provide necessary bookends to this dissertation, providing clarity with regard to the researcher's values and perspectives brought to the study, which can then be used to view the findings and subsequent propositions.

The method comprises a triangulation of literature review (contextual and integrative), auto-ethnographical narrative through reflexive inquiry, and peer-review to arrive at research findings grounded in documented evidence and personal experiences in the higher education sector. Multiple sources of information are used within the process of reflexive inquiry, and peer review is also used to provide a credibility check on the interpretation of the experiences, and to further inform the elements of curriculum renewal and model development.

The method is reflected in the structure of this document, where:

– The findings of the contextual literature review are presented in Chapter 1.

– The findings of the integrative literature review are presented in Chapter 3.

– The process of reflexive inquiry and findings are presented in Chapter 4.

– The peer review process and findings are presented in Chapter 5.

Ultimately the process of reflexive inquiry provides a supporting role to the literature reviews, which all inform the model for rapid curriculum renewal presented in Chapter 6.

References

[1] Patton, M. (2002) *Qualitative Research and Evaluation Methods*, 3rd Edition, Sage Publications.

[2] Denscombe, M. (2007) *The Good Research Guide*, 3rd Edition, McGraw-Hill International.

[3] Creswell, J. (1994) *Research Design: Qualitative and Quantitative Approaches*, Sage Publications, London.

[4] Taylor, S. and Bogdan, R. (1998) *Introduction to qualitative research methods: A guidebook and resource*, John Wiley & Sons, New York.

[5] Denscombe, M. (2007) *The Good Research Guide*, 3rd Edition, McGraw-Hill International.

[6] Smith, J. (1983) 'Quantitative versus qualitative research: An attempt to clarify the issue', *Educational Researcher*, vol 12, no 3, pp6-13.

[7] Creswell, J. (1994) *Research Design: Qualitative and Quantitative Approaches*, Sage Publications, London.

[8] Wolcott, H. (1992) 'Posturing in Qualitative Inquiry' in LeCompte, M., Millroy, W. and Preissle, J. (eds) *The Handbook of Qualitative Research in Education*, Academic Press Inc.

[9] Pitman, M. and Maxwell, J. (1992) 'Qualitative Approaches to Evaluation: Models and Methods' in LeCompte, M., Goetz, J., Preissle, J. and Millroy, W. (eds) *The Handbook of Qualitative Research in Education*, Academic Press Inc, p41.

[10] Creswell, J. (1994) *Research Design: Qualitative and Quantitative Approaches*, Sage Publications, London, p5.

[11] Firestone, W. (1987) 'Meaning in method: The rhetoric of quantitative and qualitative research', *Educational Researcher,* vol 16, Issue 7, pp16-21.

[12] Guba, W. and Lincoln, Y. (1998) 'do inquiry paradigms imply inquiry methodologies?' in Fetterman, D. (ed) *Qualitative Approaches to Evaluation in Education*, Praeger, New York, pp89-115.

[13] McCracken, G. (1988) *The Long Interview*, Sage Publications, California.

[14] Creswell, J. (1994) *Research Design: Qualitative and Quantitative Approaches*, Sage Publications, London, p8-10.

[15] Patton, M. (1990) *Qualitative Evaluation Methods*, Sage Publications, Newbury Park, California.

[16] Guba, E. and Lincoln, Y. (2005) 'Paradigmatic Controversies, contradictions, and emerging confluences' in Denzin, N. and Lincoln, Y. (eds) *The SAGE Handbook of Qualitative Research,* Sage Publications, Thousand Oaks, Chapter 8, p201.

[17] Susman, C. and Evered, R. (1978) 'An Assessment of the Scientific Merits of Action Research', *Administrative Science Quarterly,* vol 23, no 21.

[18] Denscombe, M. (2007) *The Good Research Guide: For Small-scale Social Research Projects*, 3rd Edition, McGraw-Hill International, Chapter 7: Mixed Methods, p108.

[19] Dempster, N. (2009) Personal communications with Professor Neil Dempster, School of Education, Griffith University, 13 February 2009.

[20] Dempster, N. (2009) Personal communications with Professor Neil Dempster, School of Education, Griffith University, 13 February 2009.

[21] Layder, D. (1998) *Sociological Practice: Linking Theory and Social Research*, Sage, California, p2.

[22] Layder, D. (1998) *Sociological Practice: Linking Theory and Social Research*, Sage, Thousand Oaks, California, p5.

[23] Layder, D. (1998) *Socoalogical Practice: Linking Theory and Social Research*, Sage Publications, p9.

[24] Layder, D. (1998) *Sociological Practice: Linking Theory and Social Research*, Sage, Thousand Oaks, California, p7.

[25] Layder, D. (1998) *Sociological Practice: Linking Theory and Social Research*, Sage, Thousand Oaks, California, p9.

[26] Flick, U. (1998) *An Introduction to Qualitative Research: Theory, Method and Applications*, Sage Publications, London, p229, cited in Denzin, N. and Lincoln, Y. (eds) (2003) *The Landscape of Qualitative Research: theories and issues*, 2nd Edition, Sage Publications.

[27] Rocco, R., Bliss, L., Gallagher, S., Perez-Prado, A., Alacaci, C., Dwyer, E., Fine, J. and Pappamihiel, N. (2003) 'Chapter 23: The Pragmatic and Dialectical Lenses: Two Views of Mixed Methods in Education' in Tashakkori, A. and Tedue, C. (eds) *Handbook of Mixed Methods in Social and Behavioural Research*, Sage Publications, pp596-597.

[28] Tashakkori, A. and Tedue, C. (eds) *Handbook of Mixed Methods in Social and Behavioural Research*, Sage Publications.

[29] Rocco, R., Bliss, L., Gallagher, S., Perez-Prado, A., Alacaci, C., Dwyer, E., Fine, J. and Pappamihiel, N. (2003) 'Chapter 23: The Pragmatic and Dialectical Lenses: Two Views of Mixed Methods in Education' in Tashakkori, A. and Tedue, C. (eds) *Handbook of Mixed Methods in Social and Behavioural Research*, Sage Publications, pp596-597.

[30] Green, J. and Caracelli, V. (eds) (1997) 'Advances in mixed-method evaluation: The challenges and benefits of integrating diverse paradigms', and 'Defining and describing the paradigm issue in mixed-method evaluation', *New Directions for Evaluation*, no 74, Jossey-Bass, San Francisco, pp5-17, cited in Rocco, R., Bliss, L., Gallagher, S., Perez-Prado, A., Alacaci, C., Dwyer, E., Fine, J. and Pappamihiel, N. (2003) 'Chapter 23: The Pragmatic and Dialectical Lenses: Two Views of Mixed Methods in Education' in Tashakkori, A. and Tedue, C. (eds) *Handbook of Mixed Methods in Social and Behavioural Research*, Sage Publications, p612.

[31] Denzin, N. and Lincoln, Y. (2003) *The Landscape of Qualitative Research: theories and issues*, 2nd Edition, Sage, p5.

[32] Denzin, N. and Lincoln, Y. (eds) (2003) *The Landscape of Qualitative Research: theories and issues*, 2nd Edition, Sage Publications.

[33] Morse, J. (2003) 'Chapter 7: Principles of Mixed Methods and Multimethod Research Design' in Tashakkori, A. and Tedue, C. (eds) *Handbook of Mixed Methods in Social and Behavioural Research*, Sage Publications.

[34] Denzin, N. and Lincoln, Y. (2000) 'Introduction: The discipline and practice of qualitative research', in Denzin, N. and Lincoln, Y. (eds) *Handbook of qualitative research,* Sage Publications, London, p6.

[35] Davis, J. (2003) *Educational Innovation through Action Research in Environment Education: From Project to Praxis*, Doctor of Philosophy, Griffith University.

[36] Godfrey, E. (2003) 'The Culture of Engineering Education and its Interaction with Gender: A Case Study of a New Zealand University', Doctor of Philosophy, Curtin University, April 2003.

[37] Mutch, C. (2004) 'Context, Complexity and Contestation in Curriculum ... Studies in the New Zealand Curriculum', Doctor of Philosophy, Griffith University, March 2004.

[38] Stronach, I. and MacLure, M. (1997) *Educational Research Undone: The Postmodern Embrace*, Open University Press, Milton Keynes, cited in Mutch, C. (2004) 'Context, Complexity and Contestation in Curriculum ... Studies in the New Zealand Curriculum', Doctor of Philosophy, Griffith University, March 2004.

[39] Wright, M. (1959) *The Sociological Imagination*, Oxford University Press, New York, p196.

[40] Pinar, W. and Grumet, M. (1976) *Toward a Poor Curriculum*, Dubuque, IA, Kendall/ Hunt, cited in Marsh, C. (2004) *Key concepts for understanding curriculum,* 3rd Edition, Routledge, New York, pp210-211.

[41] Riessman, C. (2001) 'Analysis of Personal Narratives', in Gubrium, J. and Holstein, J. (eds) *Handbook of Interviewing*, Sage Publications.

[42] Denscombe, M. (2007) *The Good Research Guide*, 3rd Edition, McGraw-Hill International, p76.

[43] Waterhouse, J. (2007) 'From narratives to portraits: methodology and methods to portray leadership', *The Curriculum Journal*, Vol 17, no 3, pp 271-286.

[44] Marsh, C. (2004) *Key concepts for understanding curriculum,* 3rd Edition, Routledge, New York.

[45] Reid, K., Flowers, P. and Larkin, M. (2005) 'Exploring lived experience: An introduction to Interpretative Phenomenological Analysis', *The Psychologist*, vol 18, no 1, pp20-23.

[46] Brodkey, L. (1987) *Academic writing as social practice,* Temple University Press, Philadelphia.

[47] Reed-Danahay, D. (2007) 'Autoethnography' in Jupp, V. (ed) *The Sage Dictionary of Social Research Methods,* Pine Forge Press.

[48] Neuman, L. (1997) *Social Research Methods: Qualitative and Quantitative Approaches*, 3rd Edition, Allyn and Bacon, Massachusetts, pp80-82.

[49] Mishler, E. (1999) *Storylines: Craftartists' Narratives of Identity*, Harvard University Press, Cambridge.

[50] Laslett, B. (1999) 'Personal Narratives as Sociology', *Contemporary Sociology*, vol 28, Issue 4, pp391-401.

[51] Denscombe, M. (2007) *The Good Research Guide*, 3rd Edition, McGraw-Hill International, Chapter 7: Mixed Methods, pp107-121.

[52] Layder, D. (1998) *Sociological Practice: Linking Theory and Social Research*, Sage Publications, Thousand Oaks, California, p9.

[53] Denzin, N. and Lincoln, Y. (2003) *The Landscape of Qualitative Research: theories and issues*, 2nd Edition, Sage Publications.

[54] Denscombe, M. (2007) *The Good Research Guide*, 3rd Edition, McGraw-Hill International, Chapter 7 'Mixed Methods', pp107-121.

[55] Johnson, R. (1980) 'Three problematics: Elements of a theory of working class culture', in Clarke, J., Cricher, C. and Johnson, R. (Eds) *Working class culture,* St. Martin's Press, London, p202.

[56] Neuman, L. (1997) *Social Research Methods: Qualitative and Quantitative Approaches*, 3rd Edition, Allyn and Bacon, Massachusetts, p90.

[57] Cooper, H. (1998) *Synthesizing Research: A Guide for Literature Reviews*, 3rd Edition, Thousand Oaks, California, Sage Publications.

[58] Cooper, H. (1998) *Synthesizing Research: A Guide for Literature Reviews*, 3rd Edition, Thousand Oaks, California, Sage Publications.

[59] Neuman, L. (1997) *Social Research Methods: Qualitative and Quantitative Approaches*, 3rd Edition, Allyn and Bacon, Massachusetts, p90.

[60] Cooper, H. (1998) *Synthesizing Research: A Guide for Literature Reviews*, 3rd Edition, Thousand Oaks, California, Sage Publications.

[61] Cooper, H. (1998) *Synthesizing Research: A Guide for Literature Reviews*, 3rd Edition, Thousand Oaks, California, Sage Publications.

[62] Reed-Danahay, D. (2007) 'Autoethnography' in Jupp, V. (ed) *The Sage Dictionary of Social Research Methods,* Pine Forge Press.

[63] Nightingale, D. and Cromby, J. (Eds) (1999) *Social constructionist psychology: A critical analysis of theory and practice*, Open University Press, Buckingham, p228.

[64] Lincoln, Y. and Guba, E. (1985) *Naturalistic inquiry*, Sage Publications, Newbury Park, California.

[65] Creswell, J. and Miller, D. (2000) 'Determining Validity in Qualitative Inquiry', *Theory into Practice,* vol 39, no 3, pp124-130.

[66] Guba, E. and Lincoln, Y. (1988) 'Do inquiry paradigms imply inquiry methodologies?' in Fetterman, D. (ed) *Qualitative approaches to evaluation in education,* Praeger, New York, pp 89-115.

[67] Dukes, S. (1984) 'Phenomenological methodology in the human sciences', *Journal of Religion and Health*, vol 23, Issue 3, pp197-203.

[68] Creswell, J. (1994) *Research Design: Qualitative and Quantitative Approaches*, Sage Publications, London, p157.

[69] Creswell, J. and Miller, D. (2000) 'Determining Validity in Qualitative Inquiry', *Theory into Practice,* vol 39, no 3, pp129.

[70] Shashok, K. (2005) 'Standardization versus diversity: how can we push peer review research forward?', *MedGenMed,* vol 7, Issue 1, online publication, http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1681382/, accessed 14 August 2009.

[71] Robson, C. (1993) *Real World Research: A Resource for Social Scientists and Practitioner-Researchers*, Blackwell Publishers.

[72] Filho, W. (ed) (2005) *Handbook of Sustainability Research*, Peter Lang.

[73] Denscombe, M. (2007) *The Good Research Guide*, 3rd Edition, McGraw-Hill International, p82.

[74] Denscombe, M. (2007) *The Good Research Guide*, 3rd Edition, McGraw-Hill International, p82.

[75] Denzin, N. and Lincoln, Y. (1994) *The Handbook of Qualitative Research*, Sage Publications.

[76] Jupp, V. (2007) 'Autoethnography' in Jupp, V. (ed) *The Sage Dictionary of Social Research Methods,* Pine Forge Press, p16.

[77] Bullough, R. and Pinnegaar, S. (2001) 'Guidelines for Quality in Autobiographical Forms of Self-Study Research', *Educational Researcher*, vol 30, no 3, pp13–21.

[78] Denscombe, M. (2007) *The Good Research Guide*, 3rd Edition, McGraw-Hill International, p82.

[79] Neuman, L. (1997) *Social Research Methods: Qualitative and Quantitative Approaches*, 3rd Edition, Allyn and Bacon, Massachusetts, pp4-5.

[80] Casey, K. (1995) 'Chapter 5: The New Narrative Research in Education', *Review of Research in Education*, vol 21, Peacock Publications, pp211-253, p212.

[81] Gee, J. (1991) 'A Linguistic Approach to Narrative', *Journal of Narrative and Life History*, vol 1, pp15-39, cited in Riessman, C. (2001) 'Analysis of Personal Narratives', in Gubrium, J. and Holstein, J. (eds) *Handbook of Interviewing*, Sage Publications.

[82] Michaels, S. (1981) 'Sharing Time: Children's Narrative Styles and Differential Access to Literacy', *Language and Society,* vol 10, pp423-442, cited in Riessman, C. (2001) 'Analysis of Personal Narratives', in Gubrium, J. and Holstein, J. (eds) *Handbook of Interviewing*, Sage Publications.

[83] Riessman, C. (1987) 'When Gender is not Enough: Women Interviewing Women', *Gender and Society*, vol 1, pp172-207.

[84] Cronon, W. (1992) 'A Place for Stories: Nature, History, and Narrative', *Journal of American History*, vol 78, pp1347-1376.

[85] Cohen, L., Manion, L. and Morrison, K. (2007) 'Chapter 8: Historic and Documentary Research' in Morrison, K. (ed) *Research Methods in Education*, 6th Edition, Routledge, pp191-204.

[86] Bamberg, M. and McCabe, A. (1998) 'Editorial', *Narrative Inquiry*, vol 8, Issue 1, ppiii-v, cited in Riessman, C. (2001) 'Analysis of Personal Narratives', in Gubrium, J. and Holstein, J. (eds) *Handbook of Interviewing*, Sage Publications.

[87] Bullough, R. and Pinnegaar, S. (2001) 'Guidelines for Quality in Autobiographical Forms of Self-Study Research'*, Educational Researcher*, vol 30, no 3, pp 13–21, www.ethiopia-ed.net/images/725485830.pdf, accessed 9 June 2009.

[88] Robson, C. (1993) *Real world research: A resource for social scientists and practitioner researchers*, Blackwell Publishers, Oxford.

[89] Griffith University Human Research Ethics Committee (2007) *Guidelines to assist with the completion of the Expedited Ethical Review Checklist*, Griffith University.

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3. A REVIEW OF CURRICULUM RENEWAL LITERATURE

This chapter comprises an integrative literature review of curriculum literature, summarising what is known about the process of curriculum renewal and its application within higher education. Education researchers Gordon and Lawton remarked in the late 1970s that curriculum,

> *'has now become a central feature of arguments about the kind of society we want and the kind of educational system necessary for that society'.*[1]

Almost 20 years later, our education systems are inevitably entwined with the social, cultural, intellectual, communicative, economic, political, scientific and technological systems that are at work in the world and in communities within it. As researchers Brownell and Scarino comment,

> *'In recent years all of these systems have undergone profound and rapid change, and education systems have had to respond to this in order to ensure a future in which the quality of life of each community can be maintained and further developed'.*[2]

In this chapter, particular consideration is given to the discipline of engineering, and the concept of time-constrained curriculum renewal, henceforth also referred to as 'rapid curriculum renewal'. The question first explored is, do the statements by authors such as those above reflect a higher education system that has responded to profound and rapid change, or is the reality otherwise? Given the evidence of responses, the second question explored is, how have they been undertaken?

The chapter begins with an exploration of curriculum renewal literature (i.e. higher education curriculum development theory), with regard to what constitutes 'curriculum' and 'curriculum renewal'. A review of the discourse on undertaking curriculum renewal in engineering education for sustainable development (EESD) is then provided, including a summary of emerging elements that appear to be assisting rapid curriculum renewal. Four examples of curriculum renewal in urgent and challenging times from four other highly regulated professional programs (i.e. law, business, nursing and medicine) are then discussed with regard to possible additions and variations to the elements arising from the EESD literature. The chapter concludes with a list of elements that could inform a process of rapid curriculum renewal.

3.1 Curriculum renewal theory

3.1.1. Defining curriculum and curriculum renewal

The way curriculum is understood and theorised has changed significantly over the centuries, however, there remains considerable debate as to its meaning and practice. Nevertheless, there is some consensus among curriculum researchers regarding their desire for education to play a key role in making the world a better place, and the need to consider new knowledge and skills. Within this context, a review of the literature surrounding curriculum renewal over the last century is summarised here, exploring the question of whether the pace of curriculum renewal has remained constant, regardless of the circumstances. This is important as the subsequent direction of the literature review depends on whether there is clear evidence of timely curriculum renewal.

While curriculum may be defined as a set of educational experiences organised more or less deliberately, and while pedagogy, in contrast, is concerned with the processes of teaching that actualise that curriculum, the contemporary reality is far less delineated. Barnett and Clarke reflect that the meaning of the term is widening to include pedagogical acts and to encourage teaching styles that engage students.[3] Hence, the very concept of curriculum is continually changing, which offers both challenges and opportunities for higher education research in this field.

As discussed by Billet and Stevens, the term ‘curriculum’ is used in the literature in a number of different ways. Hence, it is important to understand what meaning is being given to the term when it is being used, due to the varying beliefs and ideologies attached to each meaning.[4] While curriculum renewal (also called ‘development’ in the first instance of curriculum construction) essentially comprises the tasks of planning, implementation and evaluation, there are a number of potential viewpoints.

For example, within recent higher education literature, education researcher James refers to the need for overall coherence of the curriculum.[5] Meyers *et al* refer to cumulatively developing students’ higher-order thinking and academic skills necessary for understanding and later personal and professional lives and a careful sequencing of curriculum to produce educationally valuable academic outcomes.[6] Hall refers to the ‘constructive alignment of the curriculum’ for students’ cumulative benefit, even though it may challenge students’ perception of what learning is about.[7] According to Glatthorn, the various viewpoints of ‘curriculum’ could be summarised as follows:[8]

– Ideal curriculum – that proposed by scholars to meet particular needs;
– Entitlement curriculum – societal views of what should be taught;
– Intended or written curriculum – what is to be taught, in the form of a syllabus;

– Available curriculum – that which can be taught through the resource of schools;
– Implemented curriculum – what is actually taught by teachers;
– Achieved curriculum – what students learn from what has been implemented; and
– Attained curriculum – a measurement of student learning.

Clearly, Glatthorn appears to consider expectations (e.g. ideals, entitlement, intentions) as well as what is taught and what is learned as further elements of 'curriculum'. Similarly, Print, in his summary of the characterisations of curriculum, includes elements of content and experiences, as well as goals such as cultural reproduction and intentions. Print describes curriculum as:[9]

– Curriculum as subject matter – a body of content to be taught;
– Curriculum as experience – educational experiences that students encounter;
– Curriculum as cultural reproduction – reflecting and reproducing societal culture;
– Curriculum as intention – what it is intended students should learn; and
– Curriculum as currere – providing continuous personal meaning for individuals.

Here the characterisation of curriculum as currere provides some time-related conceptualisation, but this is related to the actual curriculum experience, rather than how curriculum is generated and then modified over time (i.e. 'curriculum renewal').

Billet and Stevens explain that curriculum may be summarised with regard to what is intended (i.e. the 'intended curriculum'), what happens (i.e. the 'enacted curriculum') and what is experienced (i.e. the 'experienced curriculum').[10] These three components can provide a means to understand the different sets of concerns about curriculum which may give impetus for curriculum change (or 'renewal'), such as those concerns of government and potential employers who may focus on intents or outcomes (e.g. competency standards); those of teachers and trainers who have to implement or enact the curriculum and who may be concerned with how the students are taught; and those of the students themselves, who may be most interested in the quality of experiences that lead to desired outcomes.

In describing his process model of curriculum theory and practice, Stenhouse uses an analogy of a recipe in cookery, which suggests a number of ingredients that combine to form a palatable result:

> *'It can be criticized on nutritional or gastronomic grounds - does it nourish the students and does it taste good? - and it can be criticized on the grounds of practicality - we can't get hold of six dozen larks' tongues and the grocer can't find any ground unicorn horn! A curriculum, like the recipe for a dish, is first imagined as a possibility, then the subject of experiment. The recipe offered*

> *publicly is in a sense a report on the experiment. Similarly, a curriculum should be grounded in practice. It is an attempt to describe the work observed in classrooms that it is adequately communicated to teachers and others. Finally, within limits, a recipe can be varied according to taste. So can a curriculum.'*[11]

However, Stenhouse did not extend this analogy to mention how the ingredients or instructions may change for the recipe, according to how much time is available for cooking!

In his 1978 seminal essay *What is Curriculum?* Egan concluded that, 'curriculum' does not exist as a distinctive field of inquiry within education, but rather is educational inquiry, addressing the 'what' and 'how' questions and dealing with the ramifications of trying to answer the question: 'What should children learn, in what sequence, and by what methods?'[12] Egan describes curriculum as comprising a container (i.e. the experiences over the period of study) and its contents (the knowledge and skills acquired).[13] Today, curriculum theory may be broadly defined as describing the philosophy of approaches to the development and enactment of curriculum, where curriculum is a planned educational experience, conceptualised as integrating 'curriculum areas' and the 'subjects and dimensions' within them.[14]

Considering the literature, this dissertation adopts the curriculum definition by Print:

> *'Curriculum is defined as all the planned learning opportunities offered to learners by the educational institution and the experiences learners encounter when the curriculum is implemented. This includes those activities that educators have devised for learners which are invariably represented in the form of a written document and the process whereby teachers make decisions to implement those activities given interaction with context variables such as learners, resources, teachers and the learning environment'.*[15]

In his 1975 publication, Stenhouse noted that curriculum renewal is about keeping curriculum up-to-date with developments in knowledge, teaching techniques and teaching materials, in contrast to curriculum innovation which involves more fundamental changes in terms of values and beliefs, roles, aims and ways of thinking.[16] However, in the following three decades, the literature has often debated the term curriculum, which has been used broadly to mean such things as curriculum change and curriculum improvement,[17] curriculum redesign, revision, redevelopment, reform,[18] transformation,[19] and restructuring of curriculum.

Taba discusses the different levels at which curriculum renewal can occur: from the level of the individual teacher, which may be informal, through to in-service training

(conducting study groups, workshops, work conferences, and in-service courses), to the committee level which Taba sees as the chief organisational vehicle for curriculum revision, producing general guides or frameworks to proceed.[20] Consultants may also contribute, and in the more ambitious programs, a network of committees may handle different aspects of curriculum renewal.

For curriculum change to be successful, change must also be effected in the ways teachers see their subject and in the self initiated positions they take up, thus not just the formation of curriculum subjects but also constructions of the subject and of teacher subjectivity are involved. In 1998, the OECD Centre for Educational Research and Innovation report on *Making the Curriculum Work* concluded that education is a complex process which involves many players within a system. Hence, there can be no overarching theory of how educational processes operate.[21] Clearly, as Beavis noted in a 1997 conference paper, curriculum renewal comprises more than a reformation of the subject and its constituent elements.[22]

With such discourse in mind, this dissertation defines curriculum renewal to mean the redevelopment of curriculum, which may involve for one or more existing or new courses in a program, the review of past syllabi (i.e. one or more documents that include statements of the aims and objectives of course and its content), and pedagogy (i.e. the way in which the course is taught).

3.1.2. Elements relating to curriculum renewal

The sense of frustration that curriculum renewal processes are not aligned with the rate of emerging information began to be documented from the 1960s alongside the emergence of grants for curriculum renewal initiatives in school education. Bobbit opens his preface to the 1971 seminal publication *The Curriculum* noting that societal evolution has been proceeding with ever-accelerating rapidity, wherein:

> *'As the world presses eagerly forward toward the accomplishment of new things, education also must advance no less swiftly … Education must take a pace set, not by itself, but by social progress.'*[23]

The literature suggests that over the following century, in particular the latter half of the 20th Century, the higher education sector faced ever increasing demands for particular graduate skills (or 'competencies') from government, professional organisations, employers and students, resulting in increasing pressure to urgently renew curriculum across many disciplines. However, many of these are heavily regulated with regard to curriculum requirements and therefore have also been reluctant to change.[24]

Today's circumstances are quite different to the more laissez-faire milieu in the early to mid 20th Century when curriculum researchers developed methodologies for curriculum renewal that are prevalent today. For example, the senior curriculum renewal process in Australia up until the mid 20th Century was a classic example of the evolution of curriculum over time.[25] Curriculum renewal was largely incremental and marginal over extended periods, rather than a whole-of-program curriculum renewal which is bounded by time constraints. There was one major renewal process between 1914 and 1928, with the following curriculum renewal period spanning 1928 to 1956. Then followed an explosion of considerations to be embedded within the curriculum from the mid-1950s to mid-1960s, including new mathematics, new social studies, and modern language, catalysed by the organisations such as the Nuffield Foundation which provided significant funds for the development of new courses in these areas.[26]

Writing about the primary and secondary school curricula, Whitfield commented in the early 1970s that curriculum development is a pervasive activity which should be sensitive to time and place. It should hence be closely associated with national educational planning – a factor already appreciated by UNESCO but by few individual nations. Whitfield concluded that efficient curriculum reform cannot be carried out in the absence of clearly formulated national goals, as without such goals difficulties can arise over establishing priorities, and frustrations and misunderstandings can develop between the agents of change, resulting in piecemeal and incoherent innovation.[27]

In 1978 Whitfield expressed concern that effective mechanisms were not being set up to continuously appraise and modify 'new curricula of today' so that they would not become the 'old curricula of tomorrow'. As disciplines change in terms of content and insight, Whitfield surmised, so do educational objectives, and so the continual cycle of renewal must continue.[28] Without such continuing evolution, curriculum becomes stagnant as the learning expectations change.

Indeed, as far back as the 1960s Egan was scathing about the construction of curriculum that used the accumulating pace of change as a reason for not clearly specifying the 'what' dimension of curriculum.[29] In 1968 Kerr called for urgent research into the dynamics of change in the curriculum development process to be understood and to some extent controlled. He concluded that some of the changes proposed will require a revolution in attitudes and methods related to curriculum renewal,[30] reflecting in the introduction to his seminal publication *Changing the Curriculum* that reform in education often involves persuasive and enthusiastic innovators unintentionally hampering real progress because there is no rational, coherent theory, or even a set of concepts, on which to base curriculum modifications. Kerr concluded that the

curriculum renewal process has developed much as a craft develops - from long practical experience where out-moded techniques and materials are often retained due to routine (i.e. 'this is just how we do it'), and where there is no planned strategy for decision-making or evaluation. Kerr concluded that,

> *'There is need to analyse the process of curriculum planning and to identify the elements that should be the determinants of curriculum design.'*[31]

A number of studies on curriculum renewal in primary and secondary education from around the world are found in the literature, where there has been a call for timely change, and where there has subsequently been a large-scale curriculum renewal effort.[32] In 1995, researcher Kennedy discussed the similarities in curriculum renewal (reform) efforts in the UK, the USA and Australia, concurring with Coombs that there has been, *'a crisis of confidence in education itself*', relating to not being able to keep up with emerging knowledge.[33] In a 2001 TELA paper, Fien described potential pathways for Australian schools to move towards education for sustainable development.[34] In 2003 the Australian Capital Territory (ACT) convened a four year Curriculum Renewal Taskforce to direct a review of ACT curriculum and the development of a new curriculum framework for ACT government and non-government schools from preschool to year 10.

Five years later in May 2008, the federal government embarked on the most significant and rapid curriculum renewal process experienced to-date in Australia, announcing the Australian Curriculum, Assessment and Reporting Authority (ACARA), which would be responsible for instigating a national curriculum from Kindergarten to Year 12 in specified learning areas over the following 5 years, including a national assessment program, and a national data collection and reporting program that supports analysis, evaluation, research and resource allocation and accountability and reporting on schools and broader national achievement. Guided by the 2008 *Melbourne Declaration on Educational Goals for Young Australians*,[35] the new national curriculum is intended to *'equip all young Australians with essential skills, knowledge and capabilities for a "globalised world" and "information rich workplaces".'*[36] In discussing the national reform process, Singh notes that this action follows a 20 year history of pushes for national curriculum in Australia, including the *Hobart Declaration* (1988),[37] the *Adelaide Declaration* (1998),[38] and the *Melbourne Declaration* (2008)[39]. Singh reflects that,[40]

> *'The rapid and continuous growth in knowledge means that curriculum documents need to be regularly reviewed and revised. Concerns have been raised that current processes of curriculum renewal have not been keeping pace with new knowledge generation.'*

Elsewhere in the education sector, universities around the world have become increasingly aware of the need to be able to demonstrate, in a quantifiable manner, skills and attributes that their graduates are imbued with during their learning experience.[41] As Roberts reflected in a 1997 paper, higher education is experiencing a period of unprecedented societal change, involving a re-think of curriculum composition of such drastic proportions that it has been called a paradigm shift.[42] Researchers Barnett and Coate reflect that the challenges of curriculum renewal must themselves be complex in character, posing considerable challenges to academia, requiring an in-depth understanding of the nature of the challenges and how they can be addressed.[43]

A number of authors also reflect on the innately slow and arduous process of curriculum renewal, which must occur due to the nature of the educational field. For example, Billet and Stevens comment in their summary of the literature, administrators who may be impatient for changes to be implemented sometimes mistakenly expect that innovative practices will proceed with just written or oral directions. However, the reality is that effective change takes time.[44] Furthermore, much of an educator's practice is private, where external regulation is often impractical or difficult to monitor.[45] American author Howard reflects that at the university level there are major disciplines that encompass a suite of courses for which there is the opportunity to redesign a coherent curriculum where students can broaden and deepen their understanding through the coursework. However, Howard concludes that, *'the idea is simple, but the work is hard'*.[46]

Hence, curriculum renewal is a significant matter to be addressed within higher education for two reasons: firstly effective curriculum is significant for the well-being and effectiveness of higher education; and secondly the topic has been consistently underplayed, even neglected in the past. According to Barnett and Coate[47] and authors such as Heywood,[48] curriculum still remains relatively invisible, continuing to be noticeably absent from public debate about higher education. Over the last few decades, tertiary educators have only just begun to pay attention to address what is taught, how it is taught, and how learning is assessed.[49,50] Given the lack of literature discussing the pace of curriculum renewal, the focus of the review is now turned to identifying core elements of curriculum renewal in the literature, to see whether there are aspects of these elements that are time-dependent.

In early curriculum theory development, Herrick and Tyler advised the importance of defining just what kinds of elements will serve satisfactorily as organising elements. Furthermore, in any given curriculum it is important to identify which elements will be used.[51] Taba discussed ways to identify the elements within curriculum renewal, given the lack of information about these elements available in the literature at the time. She

suggested one way could be to consider the major points about which decisions need to be made in the process of curriculum renewal, where these decision points could then become macroscopic elements of the curriculum.[52] Using Taba's perspective, the following paragraphs identify elements that are core to curriculum renewal.

Generally speaking, numerous curriculum theorists over the last half century – from Tyler,[53] Taba,[54] Bobbit,[55] Stenhouse,[56] and MacDonald and Walker,[57] to Grundy[58] Cornbleth,[59] and Marsh[60] – have produced curriculum models which highlight the need for the educator to take account of the circumstances within which curriculum needs to be renewed, and then to meet these observed needs by developing and formalising many document-related elements of curriculum design and development, including for example, curriculum goals, objectives and purposes and learning outcomes. This includes reviewing the type of content and processes that students need to engage with, where change in one area inevitably leads to change in other areas.[61] These theorists have also developed standards, assessment practices and review procedures, and have discussed the types of resources necessary to achieve it. In summary, three core elements relating to curriculum renewal are apparent from the curriculum renewal literature:

1. **Understanding the purpose of the curriculum:** The curriculum literature places importance on the educator first evaluating the context (or 'intention') of the curriculum, defining what should be taught and to whom (i.e. including aims, objectives, outcomes or statements of intent), considering philosophical, sociological, economic, political, structural, logistical, and historical factors. This context is then used to define the goals (or key focus areas) for the curriculum. An important aspect is meeting internal and external requirements, for example with regard to government or professional body standards, and other requirements relating to issues such as quality, indigenous content, equity, and ethics.
2. **Identifying knowledge and teaching methods:** The curriculum literature also places importance on identifying knowledge or content to include, teaching methods to employ, and developing corresponding content and assessment. This may arise through a systematic 'top down' approach driven by, for example, external legislative or accreditation requirements, or an organic 'bottom up' approach driven by educators who begin to act from a position of interest. Alternatively the approach may be driven in part by external requirements, and in part by the individual. Similarly, the teaching method and hence organisation of the content may be in the form of subjects or units, or less structured topics for investigation in the form of, for example, problem based learning.

3. **Undertaking processes for monitoring and evaluation:** A key element in the curriculum renewal literature is the need for a regular cycle of trial, evaluation and revision to ensure healthy curriculum. This involves efficient and effective course administration, and course evaluation i.e. through student evaluations regarding the course, focus groups, and reflective reporting). Improving the quality of education is a complex and challenging process which requires a systemic approach to educational change, involving the education system as a whole, and comprising regular cycles of research, development, trialling, evaluation and review.

However, while these elements provide significant guidance on systematic curriculum construction, they focus on the 'what' (i.e. content) and 'how' (i.e. the educational experience and pedagogy) of curriculum design and development, and do not consider the implications of 'by when' (i.e. the timeframe that curriculum design and development should proceed).

3.1.3. Curriculum models addressing curriculum renewal

Given the lack of consideration of time within the three core elements of curriculum renewal, a review of historical literature is now presented, which explores a number of influential curriculum models for evidence of time-related considerations. This review spans the spectrum of classical rational/objective approaches to participatory dynamic/ interactive approaches, considering curriculum as: a body of knowledge/product; as process; as praxis; and as context.[62]

3.1.3.1. Classical rational/ objective approach

Within the literature, numerous models consider a largely linear and product-oriented paradigm, and often comprise a sequence of rigid approaches to the curriculum development process, as shown in Figure 3-1.

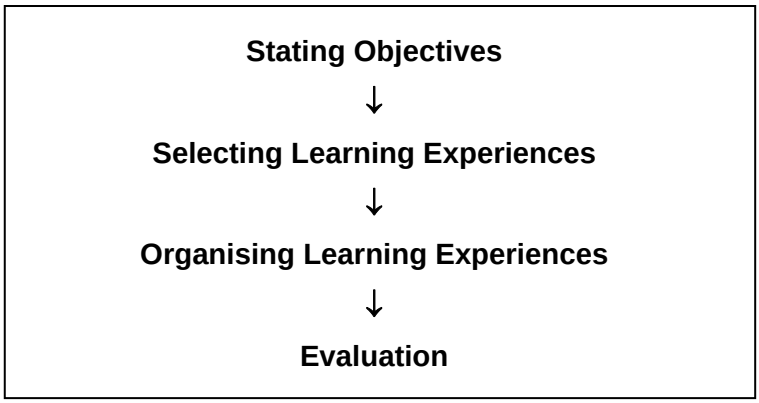

Figure 3-1. Tyler's model of curriculum development

Source: Brady[63]

Two major perspectives exist within this approach, both assuming that all interested groups - including teachers, students, communities and employers - agree on the educational goals and thus dialogue and consensus building (i.e. iterative development) among groups are not required:

– *Curriculum as a body of knowledge to be transmitted ('syllabus')*, where the educator is primarily concerned with developing content and subjects. In this approach curriculum is still equated with a syllabus, and planning is likely to be limited to considering content or knowledge to be transmitted. Education is the process by which this knowledge is delivered to students by the most effective methods that can be devised.[64]

– *Curriculum as an attempt to achieve certain ends in students ('product'):* where education is seen as a technical exercise, with objectives set, plans drawn up, applied, and then outcomes (products) measured.**[65]** This is considered to be the dominant mode of describing and managing education, growing in influence since the late 1970s with the rise of vocationalism, work integrated learning and concern with graduate competencies.

Thinking about curriculum theory and practice as 'product' was heavily influenced by the development of management thinking and practice by Frederick Taylor in the early 20th Century, a mechanical engineer by training whose career was focused on making American industry more efficient. Taylor reasoned that the emerging profession of efficiency experts should be able to identify precise steps that each worker should undertake as part of a larger system, then optimise their performance.[66] Bobbitt's curriculum planning procedures (referred to as job analysis) adapted Taylor's work, where the curriculum was comprised of the school experiences needed to enable children to do the activities that adults undertook to fulfil their various roles in society.[67,68] However, it does not appear that Bobbitt extended Taylor's efficiency reasoning into considering the time dimension of curriculum renewal; he remained focused on the 'what', rather than 'by when'.

Building on Bobbit's work in the mid 20th Century, Tyler[69] called for the application of four corresponding principles in developing any curriculum: defining goals, establishing corresponding learning experiences, organising learning experiences to have a cumulative effect, and evaluating outcomes. These principles subsequently became the accepted approach to curriculum development for almost three decades, and they still guide the essential questions of curriculum development today.**[70]** However, a number of issues and criticisms are documented in the literature with this approach to curriculum theory and practice, including a lack of social vision or program to guide the

process of curriculum construction, a linear 'ends-means' view of education that is solely focused on employer needs, and reliance on measurement despite the uncertainty about what is being measured and how the impact of particular experiences can be accurately measured.[71,72] In an attempt to overcome these weaknesses, in the mid-1980s Wheeler added an iterative component to the process, as summarised in Figure 3-2.

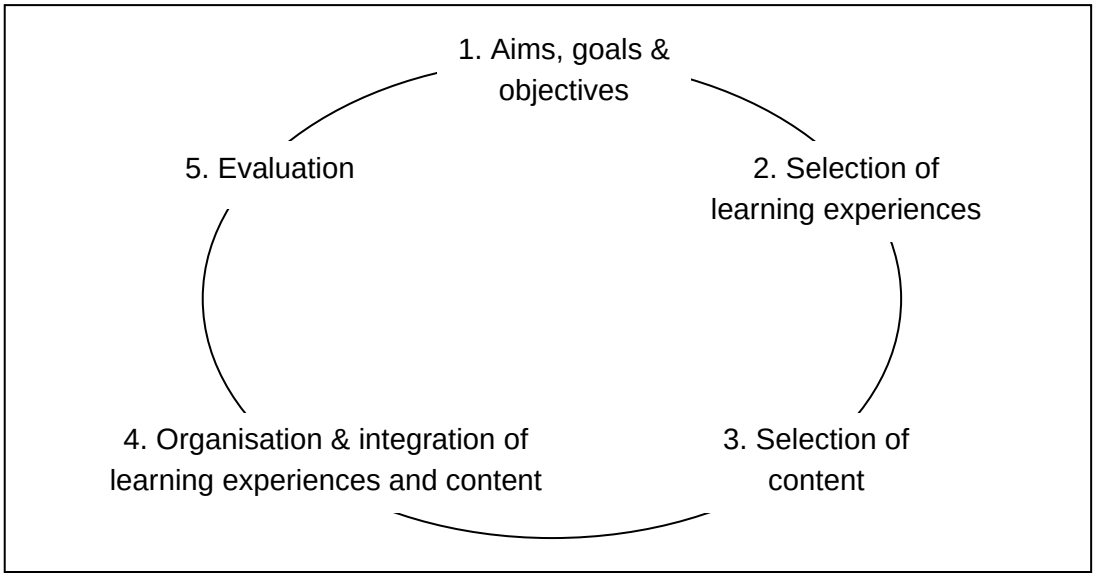

Figure 3-2. Wheelers cyclical model of curriculum development

Source: Billet and Stevenson[73]

Researchers Nicholls and Nicholls also added a situational analysis step, which provided more context for the educator to then select and organise the teaching methods and content.[74] However, this cyclical approach still results in the situation where changes may not occur until the cycle has run its course.[75] Furthermore, the situational analysis step does not include guidance on whether there are any permutations if the situation requires accelerating the curriculum renewal process.

3.1.3.2. Participatory dynamic/ interactive approach

Within the literature, numerous models also take a 'participatory/ interactive' approach, following a subjectivist, iterative and process-oriented paradigm. This approach is thought to address the lack of participation and interaction among the various interested groups or educational stakeholders which is a common criticism of the classical rational/ objective approach discussed above. Models address curriculum as process and praxis, which are described in the following paragraphs:

– *Curriculum as process:* In response to Tyler's approach, in the 1970s Stenhouse advocated principles that emphasised empiricism and process for selecting content, developing teaching strategies, sequencing learning experiences and assessing

student strengths and weaknesses, with an emphasis on what actually happens in the classroom and what teachers do to prepare and evaluate rather than on the behavioural objectives and tight hierarchical learning tasks associated with the objective approach. [76,77] Taba,[78] a student of Tyler, developed the *Rational Planning Model* in the 1960s shown in Figure 3-3, based on Tyler's model. Critics of this model point out that this approach is still relatively rigid, specifying the ends before engaging in any given activity.[79] However, it does allow the developer to change the order of planning, and allows the developer to react to situations in determining what sequence of elements is most appropriate.[80]

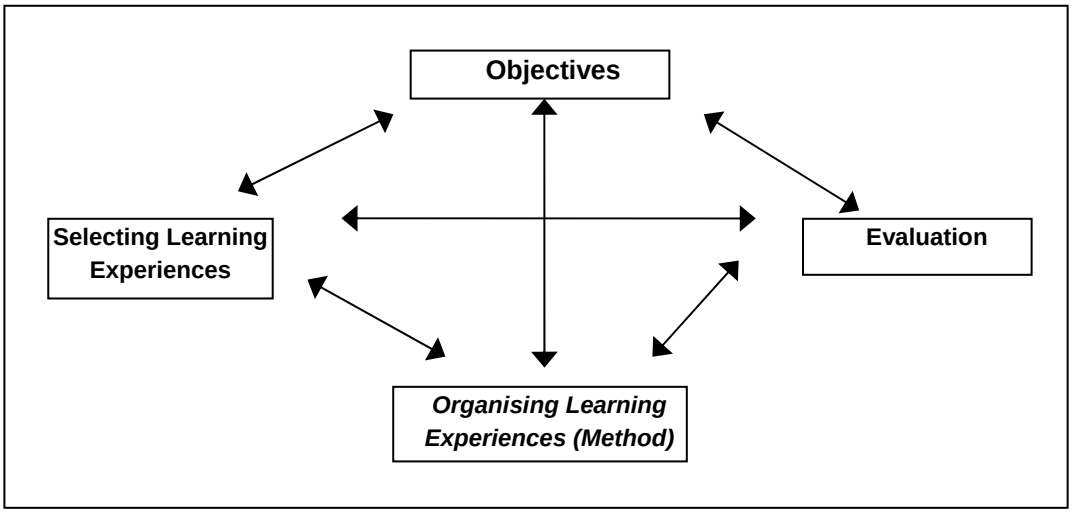

Figure 3-3. Taba's model of Curriculum Development

Source: Brady[81]

– *Curriculum as praxis:* The praxis model of curriculum theory and practice, as discussed by Grundy[82] in the late 1980s, builds on the process model, making an explicit commitment to emancipation, where action is not simply informed, but also committed. In this approach the curriculum itself develops through the dynamic interaction of action and reflection.[83] This model grew out of Stenhouse's process model, which added the element of informed and committed action, advocating a shared idea of the common good.

Many dynamic models were subsequently developed in the field, recognising that curriculum development can commence at any point and proceed in any order with many contributing variables at any point in time. An example of such a model which was developed by Walker, is provided in Figure 3-4.

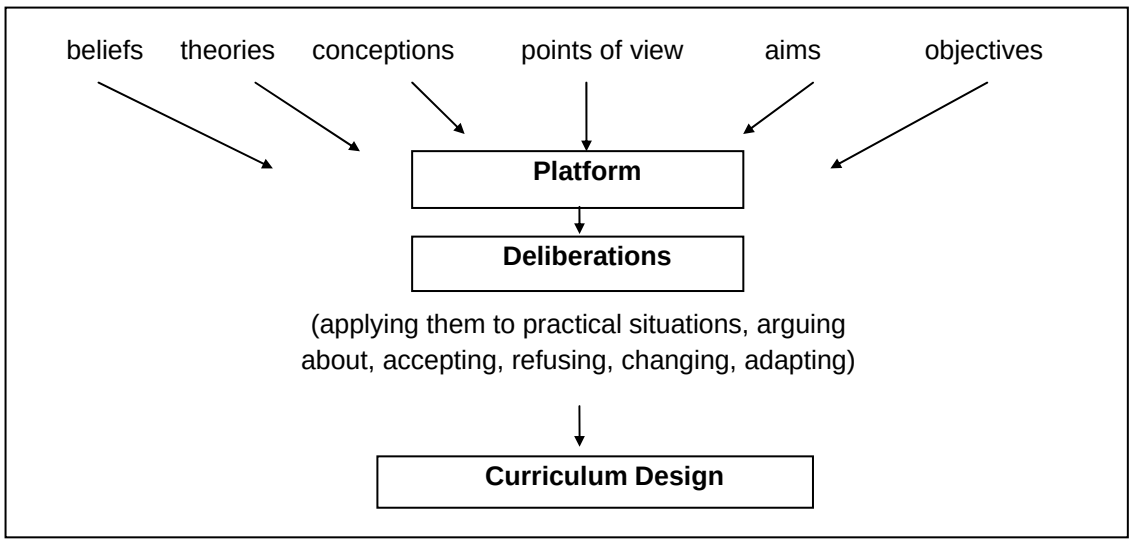

Figure 3-4. Walker's dynamic model of curriculum development

Source: Print[84]

Comparing these approaches to the more classical/ rational approaches to curriculum theory and practice, there are a number of differences, as summarised by Smith.[85] Firstly, process models use experimentation rather than prescriptive procedures. Curriculum also needs to be tested and verified by each teacher, unlike a product-based curriculum package that could be delivered anywhere. Furthermore, content and means develop as teachers and students work together, and interactions are the focus, where the learners have a clear voice in the way the learning evolves.

The process approach can therefore lead to very different methods for curriculum renewal depending on the quality and enthusiasm of the educators, and can result in a high degree of variety in content. As Stenhouse comments, the process approach is essentially a critical model rather than a marking model.[86] A popular criticism of the praxis approach (especially as it is set out by Grundy[87]), however, is that it does not place a strong enough emphasis upon context; that is, the environment ('milieu') within which the curriculum takes place. Furthermore, there is no place in these models for considering the timeframe for curriculum renewal.

3.1.3.3. Curriculum in context approach

The consideration of context (i.e. temporal issues) in curriculum renewal is increasingly commonplace, with processes beginning to acknowledge the importance of a situational analysis of the field being taught, with regard to new knowledge and skills, and its impact on employer needs regarding graduate attributes. However, this is a relatively recent phenomenon.

Dewey[88] in the late 1930s, and later Jackson[89] in the late 1960s, discussed context as being 'collateral learning' or the 'hidden curriculum' that takes place which is not necessarily planned, but which forms a key component of the students' experiences. In the 1970s Reynolds and Skilbeck were among the first curriculum writers to recognise the importance of context in the curriculum renewal process.[90] Their 'Situational Model' emphasises a thorough consideration of relevant external and internal factors, although the pace at which curriculum renewal should take place does not feature.

In the 1990s, Cornbleth wrote of curriculum as an ongoing social process comprised of the interactions of students, teachers, knowledge and milieu.[91] Cornbleth concluded that by treating curriculum as a contextualised social process, the notion of hidden curriculum becomes redundant – by staying in touch with milieu as the curriculum is built, it is not hidden but rather a central part of the process. Hence, there is a place for discussion of potential time constraints as a factor within this approach, although no evidence of such discussion.

3.1.3.4. Conclusion

It is clear from the review of significant work in the field of curriculum renewal, that in all of the assumptions about curriculum construction, development and implementation, there are no timeframes attached. Rather, the models of curriculum renewal contain a number of concepts such as aims and objectives, content, methodology, resource usage, assessment and evaluation, which are denoted with identified interactions, but which do not discuss robustness should there be time constraints imposed on the curriculum renewal process.

3.1.4. Higher education models addressing curriculum renewal

In the absence of time-related discourse in curriculum renewal literature, higher education literature is now reviewed for evidence of processes for time-constrained curriculum renewal. The review is based on a summary of the literature on curriculum in higher education provided by Howard in 2007,[92] with respect to the evolution of thought from the key authors discussed above. In particular, Howard's review highlights Knight, Barnett, Parry and Coate, and Parker as influential researchers in the field.

Knight[93] stresses the necessity of coherence in a curriculum, contending that it is possible to provide coherence and progression in a process curriculum as well as in a product curriculum. Barnett, Parry and Coate[94] propose a model of curriculum involving three domains of knowledge, action and self, where the way the three domains are integrated will differ depending on the subject matter These authors use an example of a history major, where the knowledge domain would be the history specialty area, the

action domain would include skills such as critical writing and the self domain would include a view of self as critical evaluator. Parker[95] expands on this work, arguing for transformational curriculum, which is centred on meta-cognition and self-direction.[96]

Three specialists in curriculum instruction and assessment, Fink,[97,98] Wiggins and McTighe,[99] provide practical guidance on curriculum renewal in higher education. Fink presents a model of integrated course design to facilitate significant learning experiences in courses, using the three major elements discussed previously. However, Fink emphasises that these components are all influenced by ituational factors such as course context, professional expectations, the nature of the subject, students, and teacher, as shown in the 'taxonomy of significant learning' in Figure 3-5.

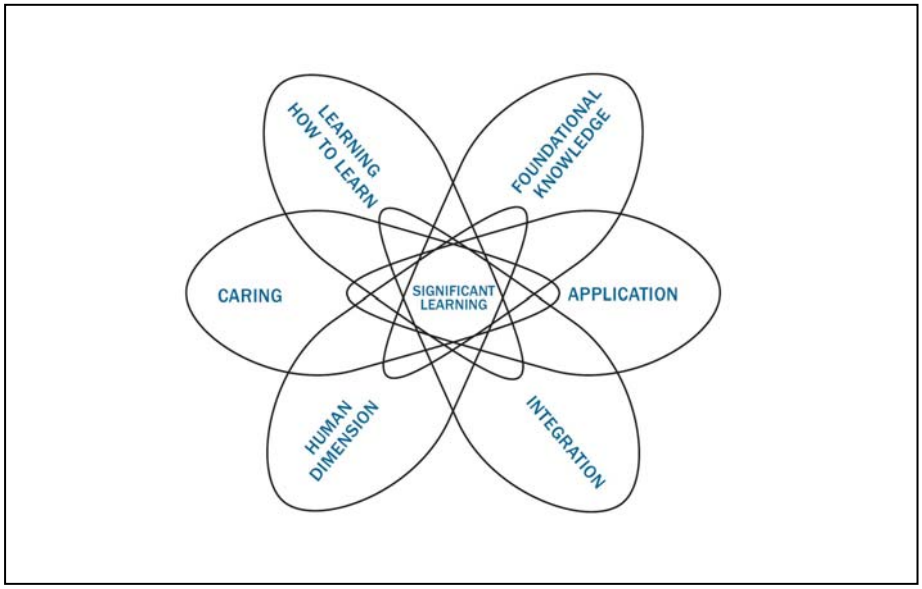

Figure 3-5. Fink's taxonomy of significant learning

Source: Fink (2007)[100]

This builds on, but is unlike Blooms' hierarchical cognitive taxonomy,[101] which classifies different objectives that educators set for students (learning objectives), where learning at higher levels depends on attaining prerequisite knowledge and skills at lower levels.

Wiggins and McTighe[102] use a 'backward design' approach, drawing on Tyler's product model in a constructivist approach. The authors start with the desired results and then work backward through a series of stages to a curriculum based on acceptable evidence of learning. The first is to identify desired results, where consideration is given to what students should know, understand and be able to do. This includes a model for establishing curriculum content through three levels of knowledge, including that which is worth being familiar with, that which is important to know and do, and that which represents an 'enduring' understanding. The authors offer a number of questions to assist in planning, from 'What needs to be taught and coached, and how should it best

be taught in light of performance goals?' to 'Is the overall design effective?',[103] but do not include questions relating to the presence of time constraints to student learning.

3.1.5. Engineering curriculum theory addressing curriculum renewal

As detailed in Chapter 1, over the last decade there has been increasing recognition of the need for transition in engineering education, to the point where any institution not aware of this is seen to be *'asleep at the helm'.*[104] In the absence of documented models and processes in curriculum or higher education literature, EESD literature is now reviewed to distil any time-related patterns.

According to a comprehensive analysis of engineering education literature by Heywood,[105] internationally, engineering education reform has a relatively long but slow history. Changes to engineering curriculum are generally made in an internal process, whereby teachers leave out or add material based on their own teaching approaches. Heywood reflects that such a reflexive curriculum derives from a constructivist position that all knowledge is relative, therefore it may be negotiated.[106] Then, occasionally, the accumulation of changes makes necessary a major review. Heywood concludes:

> *'Like all systems, engineering education has to adjust, albeit slowly, to changes in the socioeconomic system in which it functions … Nevertheless, outside influences such as changing technology are forcing departments to make changes, and it seems from the engineering literature that research and new practices are having an impact on the curriculum process.'*[107]

The last major curriculum change in engineering was the move to what is referred to as 'engineering science', which occurred following the Second World War. Since then, the composition of core knowledge has been seen as largely unchanging.[108] In the late 20th Century, key leaders in engineering were cautioning against the complacency in the profession, outlining their concerns in several reports regarding education.[109] Former President of the American National Academy of Engineering Mr Wulf has been a leading advocate, outlining the nature of a major overhaul of engineering education for the last decade.[110,111] For example, in 1998 he advocated to the annual meeting of the American Association for the Advancement of Science:

> *'... the practice of engineering is changing. Indeed, those changes are what underlie the urgency I feel for a new approach to engineering education … So, what needs to change? A lot, I think! Most obviously, we need to focus on curriculum, pedagogy, and diversity.'*[112]

Engineering literature regularly discusses the need for, and challenges of curriculum renewal in three main areas, namely 'theory' (fundamental principles and base theory),

'knowledge/ information' (explanation of the theory in a way that can be applied), and 'application' (application of the theory and knowledge). However, there are relatively few projects developing broad frameworks for curriculum renewal, or papers on the processes or the use of frameworks to guide rapid curriculum renewal, despite obvious experiences in renewing curriculum in relatively short periods of time in new topic areas such as ethics, safety, and quality assurance.[113,114,115] Most studies appear to be focused on developing individual courses, and only some papers discuss the curriculum renewal context.[116,117] Two models discussing systemic change in engineering curriculum include:

– *Walkington's Model:* Heywood references Walkington's 2002 paper published in the *European Journal of Engineering Education*[118] as a key contribution to engineering education literature. In her paper, Walkington presents a model for bringing about curriculum change, which directed policy-makers to consider parameters in addition to those traditionally addressed, and recommended a holistic view of curriculum and how curriculum change takes place. Walkington concluded that curriculum change is not an easy exercise, where those who intend to bring about change need to understand the system and the culture that they wish to change, (i.e. its external and internal dynamics). In the list of considerations that Walkington develops, there is no mention of time constraints to curriculum renewal, although this could be implied from considerations such as, 'Flexibility to fit within existing curriculum renewal structures, as well as country and international accreditation requirements', and 'Achievability within the budget and resourcing constraints common to engineering departments in an increasingly competitive industry'.

– The 'CDIO' (Conceive, Design, Implement and Operate) initiative which provides a framework for planning curriculum and outcome–based assessment, centred around a professional engineering approach of 'conceiving, designing, implementing and operating'.[119] Led by the Massachusetts Institute of Technology (MIT), more than 100 leading engineering schools across the US, Canada, Europe, Africa, and the Asia-Pacific region have committed to introduce a number of principles into their engineering curriculum using this framework, including sustainable development. However, as acknowledged by researchers in the 'CDIO' stream of the 2009 Australasian Association of Engineering Education Conference, a recognised shortfall in the current CDIO process is the lack of consideration of sustainability as a central theme.[120,121] Furthermore, the framework does not provide advice on how to undertake curriculum renewal under time constraints.

Heywood concludes that, irrespective of the model used, the combination of elements

in curriculum design, assessment and evaluation will require a substantial change in the culture of the organisational unit responsible for the delivery of the curriculum.[122] With this context in mind, approximately 120 papers and articles (many of which are referenced in Chapter 1, see Table 1.3) were reviewed for patterns in pedagogic activity that accompanied curriculum renewal experiences. Three types were identified:

– *A period of ad hoc exploration ('Ad hoc'):* This type of curriculum renewal appears to comprise a number of staff initiated and lead activities involving one or more staff who have a particular interest in sustainability (and who may not be part of senior management). This activity appears to be driven by staff, continuing for the duration of the individual's investment in such activities. They often appear to be closed or curtailed due to larger institutional programming or resourcing decisions that do not recognise a need to continue the innovation (e.g. course consolidation).

– *A period of flagship course adoption ('Flagship'):* This type of curriculum renewal appears to be led by the department, where a decision is made to offer one or more sustainability focused courses within the program; often referred to as 'flagship' courses or modules within courses. In many examples this followed a period of *ad hoc* exploration, but some literature also suggests that it can be a new initiative. This type of renewal may include one or more specific courses targeted at one or more dimensions of sustainability, such as 'sustainable energy systems'. Departments seem to formally establish these new 'flagship courses', offered in combination with existing program offerings and relying on one or a few staff. In some examples, the flagship is not a course, but rather a new module in a course.

– *A period of full integration ('Integration'):* This type of curriculum renewal appears to be evident only in examples where strategic approaches were adopted for systematic integration of sustainability content within every course in the program; few examples were available in the literature. In these examples, faculty within the department were tasked with assessing and advising how to proceed with implementing a full curriculum transition to EESD, resulting in a period of gradual integration of sustainability content into the curriculum.

It appears that these types of activities are operating largely in sequence, or in 'phases', which could be said to broadly define the current process of curriculum renewal (for example Lundqvist *et al*[123] in Sweden, Fenner *et al*[124] in England, Olorunfemi and Dahunsi[125] in Africa). Furthermore, on occasion, some institutions seem to be accelerating the process of curriculum renewal through contracting the timeframes for one or more of these phases (for example Onuki and Takashi[126] in Japan, Carew and Therese[127] in Australia, and Allenby *et al*[128] in America).

3.1.6. Conclusion

In conclusion, the literature defining curriculum and curriculum renewal is focused on issues of systematic curriculum design and development, with many perspectives to consider. However, there is almost no consideration for the pace of construction, implementation, or review.

The curriculum renewal literature contains some references to concern about curriculum development in a rapidly changing world. However, in spite of writing by authors such as Bobbit and Egan in the late 1960s, and much more recently Barnett and Coate, and MacDonald and Walker, it is evident from the literature that there is a lack of discussion about pacing the process of curriculum renewal, particularly when there are time pressures. Despite the move towards 'curriculum as praxis' and 'curriculum in context', consideration of environmental influences has not addressed a key environmental influence, namely time available for curriculum renewal, and processes that could achieve curriculum renewal in a timely manner.

The engineering curriculum renewal literature also highlights few documented studies on the curriculum renewal processes or the use of frameworks to guide transitions despite obvious experiences in renewing curriculum in relatively short periods of time in new topic areas such as ethics, safety, and quality assurance. Furthermore, two curriculum renewal models gaining popularity do not provide reflection on whether the process may be affected by time constraints, or if so, how.

A review of more than 120 papers on the topic of engineering education for sustainable development has observed three 'phases' of curriculum renewal activities leading to a renewed curriculum, referred to here as 'ad hoc', 'flagship', and 'integration'. There are examples in the literature where these processes are largely sequential, while in other examples they are undertaken concurrently. Considering how these phases may be manipulated provides a useful perspective from which to explore opportunities for accelerating existing curriculum renewal timeframes.

From this review it is concluded that there is evidence of curriculum renewal being undertaken at a faster pace, but few of these instances have been subject to systemic investigations, resulting in an absence of literature on the topic of rapid curriculum renewal. If there are elements of curriculum renewal that are supporting this acceleration, then they should be evident in documented experiences. Hence, the remainder of this chapter focuses on investigating curriculum renewal experiences in the area of EESD, in addition to four other disciplines (i.e. law, business, nursing and medicine) which are observed to have undergone time-constrained curriculum renewal.

3.2 Curriculum renewal experiences in EESD

Given the limited information about time-constrained curriculum renewal as discussed above, and further to the exploration of urgent and challenging times in Chapter 1, this chapter now presents findings of the exploration into engineering education for sustainable development (EESD) literature. Specifically, the review asks 'are there elements within this discipline example that appear to be supporting rapid curriculum renewal?'.

Building on the literature regarding curriculum in context, the mechanisms and considerations identified of the literature review (including peer review as documented in Chapter 5), are grouped into six 'elements' that appear to support rapid curriculum renewal:

- awareness raising and developing a common understanding;
- identifying and mapping graduate attributes;
- curriculum auditing;
- content development and renewal;
- bridging and outreach; and
- campus integration.

3.2.1. Awareness raising and developing a common understanding

Within the context of engineering education for sustainable development, a number of research initiatives internationally have identified the important role of awareness raising among educators and students, to support accelerated curriculum renewal. It is also critical to develop a common understanding, about what sustainable development means to the department and the curriculum, including how it relates to staff and student career aspirations.

For example, the UK Higher Education Funding Council for England (HEFCE) published a report in 2007, titled *Strategic Review of Sustainable Development in Higher Education in England.* The report concluded that sustainable development activity is very disparate in the Higher Education Institution (HEI) sector, and is widely dispersed within different HEIs.[129] The HEFCE report also concluded that HEIs have different perceptions of sustainable development and how it should be pursued (if at all) within the institution. This report clearly defined the importance of staff engagement in achieving curriculum renewal, noting that in addition to the HEFCE's role supporting teaching committees within higher educations, HEIs will need to start teaching sustainability knowledge and skills because they want to, and they will decide how it is to be incorporated.

A number of professional bodies have been developing guidance documents over the last decade, to clarify for engineering departments how the shifting requirements to EESD may be met. For example, the UK Royal Academy of Engineering (RAE) produced a 2005 report *Engineering for Sustainable Development: Guiding Principles,*[130] aimed at academic teaching staff within engineering departments or schools in the UK wanting to embed principles of sustainable development into curriculum. This report was also followed by a 2006 report on *Educating Engineers for the 21st Century: The Industry View*.[131] Since 1998, the RAE has also operated a scheme for the appointment of Visiting Professors in Engineering Design for Sustainable Development at universities in the UK to assist in the generation of teaching materials to enhance the understanding of sustainability and sustainable development among academic staff and students alike.[132]

HEIs appear to be resourcing such awareness raising endeavours. For example, in 2008, Oregon State University – one of America's top 25 'green colleges'[133] – employed a well known expert in sustainable forestry and conservation issues as its new 'Director of Sustainability Programs' in its College of Engineering, to co-ordinate and expand sustainable construction and engineering concepts throughout the college's curriculum, collaborative research and outreach programs.[134]

However, even with this element being addressed, there are a number of significant issues within engineering education, highlighted in the sub-topic of energy efficiency. In 2007, the National Model for Energy Efficiency (NFEE) funded a national survey on the 'State of Energy Efficiency Education in Australia',[135,136] which found that although there was clearly a desire to integrate energy efficiency content among staff, there was a substantial shortfall in the inclusion of theory, knowledge, application and assessment in engineering education. Even mainstream contextual topics such as 'carbon dioxide and other greenhouse gas emissions from energy generation' and 'the link between greenhouse gas emissions and global temperature change' were only covered in detail by up to a third of surveyed courses, and mentioned by less than half. Moreover, student survey results indicated only a low to moderate appreciation of how energy efficiency might be directly related to their future careers. Hence, this element clearly needs to be used with other elements to engender rapid curriculum renewal.

3.2.2. Identifying and mapping graduate attributes

Following the emergence of curriculum mapping literature in the late 1990s for primary and secondary schooling.[137,138] The identification and mapping of 'graduate attributes' appear to be gaining popularity in the HEI as a way to define the kind of graduates their programs seek to deliver, and a way for accreditation bodies to define what graduates

should be able to do within certain timeframes.[139] The engineering curriculum literature defines a 'graduate attribute' as a particular area of knowledge and/or skill that a graduate should have fully developed by the time they complete a given program of study (for example through the 'Structure of Observed Learning Outcomes' (SOLO) taxonomy described by Biggs and Collis[140]);[141] this is also referred to as a 'graduate competency',[142] 'program outcome' 'learning outcome',[143] and 'graduate capability'.[144] A set of graduate attributes can then define the qualities, skills and understandings that a department agrees its students should develop during their time with the institution.[145] In the development and refinement of the list of attributes, each attribute has one or more associated competencies (also referred to as 'sub-attributes' in the literature).

Once these are identified, the mapping technique then involves identifying content and skills taught in each course at each level, creating a calendar/ year-based chart, or 'map' for each course so that the attributes can be reviewed with respect to when and where in the program they are taught. Graduate attributes may be mapped to one or more courses, depending on the learning pedagogy within the program. Examination of such maps can reveal gaps, repetition among courses, and also opportunities for integration between courses and learning pathways.

Indeed, HEIs are facing increasing pressure from accreditation institutions, industry, professional bodies, higher education authorities and peers (for example through the CDIO network[146]) to integrate various graduate attributes, including sustainability related competencies, into their program offerings.[147,148,149,150] In Australia, a number of universities are collaborating on an 'Engineering Meta-Attributes Project' (EMAP) funded by the Australian Learning and Teaching Council, to examine a range of frameworks for mapping and reporting on the development of graduate attributes at the program level.[151] Within the EESD literature, there are numerous references to workshops where sustainability attributes are discussed, and reviewed, which are planned and undertaken over a period of weeks to months.

As discussed by Goldsmith *et al*, the resultant 'graduate attribute map' for developing each attribute must be clearly visible (i.e. demonstrated) in the curriculum, encouraging the development of a 'three-dimensional' graduate; one who has technical, personal and professional and systems-thinking/ design-based competence.[152] Appropriate language should appear in the course objectives, teaching and learning activities and assessment tasks, demonstrating student exposure to relevant knowledge and skills. The graduate attribute map can then be used to review (i.e. audit) a program as described in the following section with regard to which attributes are covered well, and which ones require further development in the curriculum. However, as Davis and

Savage conclude from their national survey, working through the graduate attribute mapping process does not necessarily mean that the outcomes will be of high quality, as evidenced by national concern in Australia surrounding the confidence of universities to meet the needs of graduates.[153]

Murdoch University in Western Australia is an example of an institution that undertook a process of graduate attribute mapping, where nine overarching graduate attributes were accepted by Council in 2003 that are now required to be met by all disciplines and programs at the university, including attributes for ethics, social justice and global perspective.[154,155] Another example is Swinburne University (Victoria, Australia), which comprises a set of key curriculum areas as the basis for reform of programs including developing social and environmental aspects alongside other skills.[156]

Within engineering, a small part of the completed map for Swinburne University's Civil Engineering program is shown in Table 3-1, developed as part of preparation for its 2008 engineering accreditation by Engineers Australia. The university's Engineering Board of Studies mapped the ten Engineers Australia graduate attributes through each of the undergraduate engineering programs offered, allowing the Engineering Board of Studies to easily compare attribute development within each program, and also across different engineering programs. As all staff were involved in the mapping process, there is now a strong sense of ownership.[157]

Table 3-1. Example graduate attribute map, using Engineers Australia's accreditation criteria

Course Code	Course Name	Graduate Attributes (Existing Accreditation)									
		Apply knowledge	Communicate Effectively	In-depth Tech. Competence	Problem Solving	Systems Approach to Design	Teamwork	Culture & Environment	Sustainable Design & Development	Professional & Ethical	Lifelong Learning
HEF1000	Professional Engineering	M	H	L	M	L	H	M	L	M	M
HES1125	Mechanics of Structures	H	L	H	H	L					M
HES1230	Materials and Processes	H	-	-	M	-	M	-	-	-	-
HES1115	Sustainable Design	M	H	L	M	M	M	M	H	M	M
HMS112	Engineering Maths 2	M	M	M	H	-	-	-	-	-	-

-	None	L	Low emphasis	M	Moderate emphasis	H	High emphasis

3.2.3. Curriculum auditing

Within the literature, there are numerous references to the urgent need understand how programs are performing with regard to sustainability content. This is discussed within the context of students learning about sustainable development in *ad hoc* ways within one or more particular courses, where exposure on the whole is not leading to the students applying sustainable development knowledge and skills in their professional life.[158,159,160] An 'audit' (also referred to as 'assessments' and 'evaluations') describes a formal evaluation of all or part of a program to assess whether the curriculum is compliant in addressing a set of criteria (e.g. a set of graduate attributes).

While there are a number of methods available for assessing how well higher education institutions (HEIs) are addressing sustainability,[161,162] and increasing literature describing such experiences, there is limited literature on how curriculum audits for the topic area of sustainability are being undertaken in engineering education. Depending on resourcing constraints and opportunities within a department, sampling may differ in the consideration of some or all course outlines, lecture material and assessment briefs, interviews with the program convenor and course convenors.

A notable example of emerging audit requirements and subsequent collaborations is in Wales, where the National Assembly Government required each HEI to undertake a curriculum sustainable development audit by the end of 2008.[163] Cardiff University's Centre for Business Relationships, Accountability, Sustainability and Society (BRASS) developed a commercial-in-confidence audit tool called *STAUNCH* in 2007,[164] which evaluates course descriptions by grading them against a number of economic, environmental and social criteria and cross-cutting themes. In collaboration with the Higher Education Funding Council for Wales all Welsh HEIs agreed to adopt a common approach to undertaking a sustainability audit of curriculum based on this work undertaken by Cardiff University.[165]

There are also some examples of institutions developing their own audit tools. In Australia, the University of South Australia audited their civil engineering program for sustainability content in 2008, deriving their own questions and analysis protocol to understand gaps and opportunities for improvements.[166] The South Australian researchers agree that there is not yet a robust prescriptive set of criteria covering sustainability related knowledge and skills for all engineering disciplines, of which departments can use to assess how well a course or program has integrated EESD into the curriculum. However, there are a number of emerging sustainability related accreditation criteria available, in the form of graduate attributes as discussed above. These outcomes-based graduate attribute criteria are sympathetic to the reality that the

nature and placement of sustainability knowledge and skills within the curriculum will depend on a number of variables, such as staff and student preferences for related graduate attributes and the critical literacies to develop them, the university context, industry affiliations, and the influence of professional organisations.

Auditing a curriculum for the development of graduate attributes is clearly only part of the assessment process in determining whether a program is achieving its intended goals. In particular, a curriculum audit does not address the potential for implementation of the designed curriculum to fail in developing the graduate attributes. Student competencies are occasionally assessed through such formats as entry and exit aptitude tests, for example the Australian Graduate Skills Assessment (GSA) developed by the Australian Council for Educational Research, which Hambur *et al* suggest could be administered to students entering university and again in the final year of a bachelor degree.[167] However, assessing student competencies with regard to education for sustainable development is discussed in the literature as being problematic due to the need to test for systemic, complex, and multidisciplinary skills in addition to straightforward knowledge about sustainability phenomena.[168,169]

3.2.4. Content development and renewal

There is strong evidence within the literature that strategic content development through informed decision making is a key element that can be used to accelerate the curriculum renewal process. For example, in the sub-topic area of energy efficiency, the 2007 NFEE survey identified that even though energy efficiency education was highly variable and *ad hoc*, there were a range of preferred options for improvement.[170] For more than half of the surveyed courses (55%), lecturers reported that their course could include more (in-depth) energy efficiency content, and more than half (52%) thought their course could include more on information about opportunities. The survey also showed a clear preference for resources to be available through open access, online learning modules (90%) as opposed to restricted access sources (6%) or intensive short courses undertaken in person (13%) or remotely (10%). Such information can assist departments with decisions about the preferred structure, content and tools for content development, as discussed in the following paragraphs.

3.2.4.1. Niche degrees and integrated degrees

There appears to be strong inertia to create new niche degree offerings that will attract students,[171,172] however, audits such as that undertaken by the University of South Australia conclude that academic staff are emphatic that sustainability not be addressed in just one (or two) sustainability courses where the authors conclude that,

'no one wants a shorthand reference to "the sustainability class."'[173] The literature also demonstrates that universities who can integrate sustainability content within their existing programs have an opportunity to attract more students to existing degree programs, and leverage off market placement, branding and notoriety already in place. For example, international leaders in engineering education such as MIT, Delft, Carnegie, Tokyo University, and UPC-Spain are demonstrating through programming, that integrating, or 'embedding', these materials across the spectrum of university curriculum, combining integrated undergraduate bachelor degrees with postgraduate (or 'graduate') specialisations in sustainable development topics, is positioning them to be leading universities in the following decades;[174] the 'new world' ivy league.

The 2008 special issue of the *European Journal of Engineering Education* included a paper comparing the efforts by leading EESD institutions, Chalmers University, Delft University and UPC-Spain to embed sustainability into their educational programs.[175] The paper concluded that the complex nature of changing needs requires strong and long term strategies, noting that the three universities appear to be converging on developing comparable strategies, based on compulsory courses for all specialisation tracks as masters and minors. Moreover, they appear to be pursuing a progressive deep curriculum revision in order to embed EESD in all programs.[176]

An example of an institution undertaking curriculum renewal towards EESD is the Royal Melbourne Institute of Technology (RMIT), which has focused on civil engineering, beginning in 2004.[177] For a number of years, the program's first year included a flagship introductory course in environmental sustainability. As part of the renewal process, the existing flagship course and another first year course in the area of communications have both been modified so that they focus on elements of EESD, under the overarching aim (e.g. a 'flagship theme' associated with one or more graduate attributes) of developing sustainability-centred design skills.[178]

The Australian National University (ANU) is an example of where an engineering department can strategically modify its existing undergraduate program to create a market niche and ensure EESD graduate attributes are addressed for all students, avoiding the risks associated with a new 'niche sustainability degree'. ANU's Faculty of Engineering and Information Technology has embedded sustainability into the mainstream bachelor degree, focusing on systems engineering, or 'whole system engineering' as the foundation, based partly on the work of The Natural Edge Project.[179] Unique in the southern hemisphere, the degree produces graduates trained to become key members in teams of engineers that provide complete or 'whole system' solutions, rather than individuals contributing sub-systems to someone else's project.

An example of where students have clearly voiced their desire to see sustainability integrated within courses beyond 'flagship courses' is within the Queensland University of Technology. In 2007, the Faculty of Built Environment and Engineering offered their inaugural first year flagship course on 'Introduction to Sustainability'. The course development began with the first candidate and Mr Hargroves facilitating two graduate attributes workshops with QUT staff, leading to the development of course notes based on the outcomes. As the Dean, Martin Betts, reported,

> *'Almost 200 of the 900 first year students enrolled in this course felt strongly enough about education for sustainable development by the end of the semester, that they signed a student-led petition to our Vice Chancellor calling for sustainability content in the rest of their degree program. This was a profound reminder to our staff that what we were doing was very important, but that we couldn't stop with just one course'.*[180]

3.2.4.2. Modular and open-source content

Within the EESD literature there was regular reference to either the building of, or use of, pre-prepared modular content to quickly increase the amount of sustainability content in engineering curriculum. This finding aligns with a 2008 Australian study on the supply and quality of engineering graduates for the 21st Century funded by the Australian Learning and Teaching Council (formerly the Carrick Institute), which concluded that,

> *'Web-based resources can certainly assist academics to develop [curriculum] and support their students learning. Resource networks… should certainly allow academic staff to spend their curriculum development time allocation to greater effect'.*[181]

Table 3-2 summarises a number of freely available and academically rigorous content resources on EESD identified from the literature, including textbooks, which can assist in providing content for curriculum renewal.

Table 3-2. Examples of curriculum renewal and supporting content resources for EESD

Content Source	Description
Massachusetts Institute of Technology Open Courseware (OCW)[182]	The Massachusetts Institute of Technology (MIT) open courseware (OCW) is a web-based publication of MIT course content. The site can be browsed by course, department or keyword to locate a specific course or topic.
United Nations Environment Program Toolkits[183,184]	UNEP in collaboration with UNESCO has just released an online 'Higher Education Toolkit on Sustainability Communications', to provide interactive research, training and practical materials on issues that can be used in marketing and communications courses.
Toolbox for Sustainable Design Education[185]	The UK Higher Education Academy's Engineering Subject Centre funded a mini-project for the development of a tool box for teaching sustainable design, for lecturers looking for guidance and material to support the development of a module.
Second Nature 'Education for Sustainability'[186]	Second Nature is US organisation helping higher education institutions prepare future professionals for increasingly complex environmental challenges. Second Nature's Resource Centre and web site is a substantial and well-used repository of materials submitted by individuals from across higher education institutions.
The Natural Edge Project online resources[187]	TNEP has developed more than 65 lectures covering a range of topic areas listed in Table 3-2, as well as review and mentoring by numerous experts in the field.
RAE Visiting Professors Scheme: Engineering Design for Sustainable Development[188]	The UK's Royal Academy of Engineering (RAE) has developed a set of engineering case studies, where each case study includes a set of documents and realistic data which describes the circumstances at each location, introductory slide presentations, and a set of guidelines and suggested exercises for lecturers.
Online text books	There are a number of recommended text books for engineering education that are freely available online. For example: – Plan B 3.0: Mobilising to Save Civilisation.[189] – Natural Capitalism: Creating the Next Industrial Revolution.[190] – Whole System Design[191].
Related Materials (broad application but not engineering focused):	
UNESCO Teaching and Learning for a Sustainable Future Multimedia programme[192,193]	A teacher education programme published by UNESCO comprising 25 modules (approximately 100 hours) of interactive activities designed to enhance the teacher's understanding of sustainable development and related themes and practical skills for integrating themes into the school curriculum. Alongside this program two other publications were developed on *'Learning for a sustainable environment'*.
Education for Sustainable Development Toolkit[194]	A toolkit developed to assist communities, schools, and institutions take the first steps toward creating an education for sustainable development program.

3.2.4.3. Barriers and benefits to content integration

While it is clear in the EESD literature that lecturers are recognising an absence of content, there is a significant lack of systemic action in integrating the content. In the example of energy efficiency education, the 2007 survey concluded that this is likely to be due to the presence of a variety of barriers to implementation.[195] For example, nearly two thirds of lecturers surveyed (58%) considered the potential for course content overload to be an issue, while more than half (52%) considered having insufficient time to prepare new materials as a challenge to such curriculum renewal.

In 2009 a follow-up survey was funded by the NFEE, to identify and investigate a shortlist of options that HEIs could consider for timely curriculum renewal in energy efficiency education at the level of the lecturer.[196] Through a literature review followed by a national survey of engineering educators, the researchers short-listed 10 favoured options amongst HEIs to integrate emerging energy efficiency content within current engineering programs, as shown below, ranging from including case study on the topic, to developing a new course. The research then investigated barriers and benefits to these options as a critical step[197] in understanding the potential for rapid capacity building at the actual level of implementation.

Table 3-3 provides a summary of the identified common barriers to one or more of the shortlisted options, highlighting that putting in place mechanisms to address any of the barriers can have multiple flow-on benefits for addressing other barriers. For example, for key staff tasked with integrating new content, setting up an annual allocation of teaching buy-out funds, or having an avenue for temporarily altering staff teaching-research-service workload allocation to engage in rapid curriculum renewal, would help to address the barrier of insufficient time for preparation, which affects 7 of the 10 options. Similarly, an annual small-grants program available for educators to pilot rapid curriculum renewal initiatives would help to address the barrier of prohibitive cost.

With such considerations in mind, HEIs can strategically allocate budget and human resourcing to enable the integration of new content – in this case energy efficiency knowledge and skills – into existing education and training programs. This could be for example through a ‘tiered’ approach, where the first three options, including the use of case studies, guest lecturers and supervised research, may immediately be targeted, with other options then implemented among various programs in the following budget cycles.

Table 3-3. Issues for implementing curriculum renewal in energy efficiency education

Key Issues for Implementation	Shortlisted Options for Curriculum Renewal									
	1.Case Study	2. Guest Lecturer	3. Supervised Research	4. PBL Topic	5. Include Assessment	6. Tutorials	7. Course Overhaul	8. Workshop	9. Field Trip	10. New Course
Common Barriers										
– Lack of available data/ information	●	●		●	●	●	●		●	●
– Lack of time for preparation	●	●		●	●	●		●		●
– An overcrowded curriculum	●		●	●		●			●	●
– Prohibitive cost	●		●	●	●	●		●	●	●
– Lack of knowledge	●	●	●	●	●		●		●	●
– Lack of value attached	●		●			●				
– Lack of industry contacts		●	●					●		
– Resistance to top-down directive			●				●			
– Students' prior learning habits					●				●	
– Lecturer apathy		●					●			
– Administrative coordination							●	●		●
Common Benefits										
– Improved marketability	●	●					●	●		●
– Cross-functionality of content	●						●			●
– Additional research opportunities		●								●
– Networking opportunities for students		●	●					●		
– Networking opportunities for lecturers		●	●					●		
– Experience in incorporating emerging concepts into curriculum			●				●			
– Addressing the time-lag for graduates			●				●			
– Improved pedagogy - problem based learning				●	●	●			●	
– Improved pedagogy – generic skills				●	●	●			●	
– Lecturer professional development		●				●				

Source: Desha, C., Hargroves, K. and Reeve, A. (2009)[198]

3.2.5. Bridging and outreach

The EESD literature includes substantial reference to bridging and outreach activities associated with accelerating curriculum renewal initiatives – in particular bridging activities with industry, and outreach activities with high schools and within the institution (i.e. through other undergraduate and postgraduate programs). Within the literature, there is also regular reference to the need for lecturers to undertake professional development. These findings are discussed in the following paragraphs.

3.2.5.1. Connecting with industry through coursework

When considering bridging to industry and government, although the content may stay the same, the mode of content delivery is likely to need some modification towards adult learning principles. For example, adult learners, broadly speaking, share the characteristics of being self-directed learners who want knowledge that is immediately practical (i.e. problem centred), and who have a growing reservoir of experiences to draw upon in learning.[199] Content delivery in these learning environments might immerse participants (both students and staff) in predicaments and problems that participants would bring with them from their workplaces, or other aspects of their lives. Such an approach makes access to the sorts of materials listed in Table 3-2 an essential ingredient, together with peer and faculty support.

In 2005, RMIT University introduced a Master of Sustainable Practice (MSP),[200] which was designed to embody adult learning principles. The program structure was a mix of monthly whole-day workshop classes in which problems were discussed, combined with the more traditional electives which provided supporting information and skills, including guest speakers, and content from Table 3-2 as elective options. The resultant multidisciplinary program was built on adult learning principles with a clear set of graduate capabilities that focused on problem solving, combined with change management, supported by the sorts of pre-prepared learning modules outlined earlier in the discussion on RMIT's undergraduate curriculum renewal.

Griffith University's Centre for Environment, Population and Health (CEPH) also provides regular intensive training opportunities for middle to senior managers across industry and government internationally on areas including environmental health, public health and environmental management, which draw on the existing courses on offer through the university.[201] Nominated for its outstanding achievements and demonstrated contributions towards positive collaborations with institutions in the Asia-pacific Region, CEPH won the state of Queensland's 2008 Education and Training International award for 'Best Practice in International Collaboration'.[202]

In China, Tongji University has been running a number of successful training programs over the past two decades through the *Training Centre of Urban Planning and Management*, for leaders and professionals of urban management and construction, drawing on a number of academic staff.[203] Once the mayors complete their initial training, the College offers them 'service for life' through a 'sodality' within the Tongji alumni association, where program participants can continue to network and share experiences, and where the Tongji College of Architecture and Urban Planning,[204,205] can assist them with planning issues.

Professor Michael Powell, Dean of the Griffith University Business School which offers a 'Master of Sustainable Enterprise' notes that the school is integrating corporate global responsibility principles across all programs because it thinks the business leaders of tomorrow should take corporate responsibility and sustainability as seriously as the bottom line, and also because many who show interest in coming to the public seminars subsequently engage in programs.[206]

3.2.5.2. Outreach to schools

Within the primary and secondary education systems there is literature discussing the need for kindergarten through to grade 12 (i.e. 'K-12') teachers to undertake professional development in engineering education, as part of the plan to stop the decline in tertiary engineering student enrolments.[207] Such professional development may also provide an opportunity for teachers to expose students to new knowledge and skills in parallel to universities embedding it within the engineering degree programs.

From the literature it was observed that universities who do not have their own materials developed, have begun outreach activities with resources already available online, such as UNESCO's 'Teaching and Learning for a Sustainable Future',[208] the ZERI Learning website,[209] and the Australian 'Teach Sustainability'[210] website where teachers can upload their own curriculum and comment on others. The *Sustainable Living Challenge* is also a national program that integrates curriculum development with a national challenge, asking upper secondary school students to engage in 'sustainable living' initiatives, which is supported by classroom learning. The challenge provides teachers with lecture materials to support their teaching, which are drawn from first year university course notes.[211]

Extra curricular education programs, such as intensive short courses, also appear to play an important role in bridging the divide to potential students, where teachers may not be receiving such professional development to expose students to such knowledge and skills within the normal school curriculum. For example, The Youth Encounter on Sustainability (a program within ETH Zurich) Program Director Michelle Grant reflects,

'With over 900 alumni from 100 different countries, the course has played an important role in sensitising upper level university students to the complex issues of sustainable development … These initiatives have a spill over effect to other students and youth, which plays an important role in further raising awareness and increases demand for sustainability education'.[212]

3.2.5.3. Inter-institutional studies

As discussed in Chapter 1, although inter-institution collaboration is still relatively low with regard to cross-institutional program offerings on sustainability topics, the EESD literature includes a number of examples of such an approach, which shares the workload of developing and delivering specialist courses, as highlighted below:

- In Japan, the Integrated Research System for Sustainability Science (IR3S) established in 2005, has developed an international Masters of Sustainability Science, in English. This has developed from an initiative running since 2005, where the University of Tokyo's Graduate School of Engineering and Graduate School of Agriculture and Life Sciences has conducted an 'Intensive Japanese Program on Sustainability Science' (IPoS), a short-term experimental sustainability educational program, in co-operation with Asian Institute of Technology (AIT), Thailand and the Massachusetts Institute of Technology (MIT), USA.[213]
- Zurich's Swiss Federal Institute of Technology's (ETH) Center for Sustainability (*ETHsustainability*) collaborates with academics from a number of institutions internationally to develop *The Youth Encounter on Sustainability* (YES) course which is also focused on undergraduate and graduate students and which has been undertaken in a number of countries to-date.[214]
- In Korea, Professor Kwi-Gon Kim directs the International Urban Training Centre (IUTC), which was established in 2007 with the support of the United Nations Human Settlements Programme (UN-HABITAT), to build the capacity of cities and towns nationally and in the Asian and Pacific region in support of the goal of sustainable urbanisation. The Centre runs a number of short course programs in collaboration with universities internationally, to bridge the knowledge gap between academia, local and central government in sustainable urban development.[215]
- In the United Kingdom, Forum for the Future is a non-government organisation which has been offering a Masters of Leadership for Sustainable Development since 1996 in collaboration with Middlesex University (UK) which validates it as a Masters in Professional Studies. Forum for the Future has now begun to develop national versions of the program internationally.[216]

- In Australia, Griffith University, University of Queensland, Monash University and the University of Western Australia have collaborated through the International Water Centre to offer a Masters of Integrated Water Management, combining expertise across four universities in a masters degree that shares delivery costs.[217]
- The Zero Emissions Research and Initiatives (ZERI) – a non-profit organisation originally formed within the United Nations University - has partnered with Politecnico di Torino in Italy to offer a one-year Masters of Systems Design, which uses a new business model of open industrial systems.[218]
- In the UK, LEAD International is a non-profit organisation that delivers training programs to business executives, government officials, academics, non-government organisations, educators and media professionals on emerging issues relevant to leadership and sustainable development, often in collaboration with the higher education sector.[219]

3.2.5.4. Engineering educator professional development

Also identified from the literature, is the significant issue within the engineering educator community internationally of academic educators not having recent industry experience.[220] As highlighted by education researcher Allan in a keynote paper to the 2009 Australasian Association of Engineering Education conference, educators need to be trained and developed to teach an understanding of competencies in the context of a global information society.[221] The 2008 Australian *Engineering Review* recognised this issue when they recommended increasing the take-up of academic positions by candidates with substantial and relevant industry experience, increasing the networking of acknowledged expertise in engineering education, increasing the take-up of industry-based study leave opportunities, and increasing the sharing of resources between research and teaching.[222]

Without formal requirements for professional development, academics who have been employed within in the higher education sector for 10-20 years may well be teaching outdated information. This problem of currency in experience and knowledge appears to be compounded by the diminishing attractiveness of academic positions and hence the difficulty, competing with the practicing sector, to attract experienced engineers into academic roles. According to Gilliot *et al* attracting and retaining qualified staff is becoming more difficult and less attractive, compared with the prestigious and exceptionally stimulating intellectual environment of 30 years ago.[223]

However, there are some examples in the literature of universities addressing this issue of knowledge and skills currency, and professional development for engineering

educators. For example the University of South Australia's approach[224] is consistent with leading Mexican researcher Lozano's perspective[225] that sustainability should be integrated into the policies, approaches and learning of all academic members, professors and the students, as well as academic directors. In the UK, the Visiting Professors Scheme has also helped to provide academics with access to current knowledge and skills.[226] The increasing availability of open-source content and online support appears to be an available mechanism for addressing this knowledge gap among engineering educators, although there is still concern that sufficient time and support is not available for academics to make use of such resources.

3.2.6. Campus integration

There appears to be a consensus in the education for sustainable development literature that curriculum renewal is significantly enhanced and underpinned by taking a whole-of-campus approach; where curriculum renewal processes are brought together with campus greening initiatives.[227,228,229] Indeed, experiences by universities such as the University of South Australia first commenced with sustainability research, and greening campus operations, including the employment of institution-wide environmental officers, in advance of education for sustainable development curriculum renewal considerations.[230]

From the literature it can be seen that integrating campus activities with curriculum could be achieved, for example, by linking a sustainability curriculum audit process with an assessment of opportunities to undertake campus greening operations; in effect 'operationalising' the curriculum. Universities operate within a broader community and so contribute to the sustainability of these communities. As the Australian Research Institute for Education for Sustainability concluded in a 2005 national review of environmental education and its contribution to sustainability in Australia, change towards sustainability in HEIs requires more than just rethinking education plans or curriculum - ultimately, learning for sustainability has implications for the core of the institutional culture, influencing decisions, management procedures and research.[231]

There are a growing number of organisations committed to greening campus operations, such as the University Leaders for a Sustainable Future (ULSF), the UK Environmental Association for Universities and Colleges (EAUC), the Australian Campuses Towards Sustainable Development (ACTS) and the US Partnership for the Decade of Education for Sustainable Development. However, the link between improving operations and accelerating curriculum renewal in the classroom is still weak. Institutions still view modelling sustainability as an option that they will pursue if they can afford it, rather than an essential component of embedding sustainable

development within higher education curriculum. For example, in reflecting on Harvard University's highly successful 10-year Green Campus initiative, founder Leith Sharp concludes that while the university may be at least five or so years ahead of other higher education institutions in America and elsewhere, given the limited current cross-over between campus operations and curriculum, this is the next challenge for the university, which can only benefit from students living through such real projects.[232]

RMIT Professor Ian Thomas summarises in a 2006 UNESCO publication the journey of HEIs globally in making the transition to education for sustainable development. He describes the need for a systemic approach, which includes: improving the environmental management of campus operations; embedding education for sustainable development; developing partnerships with other organisations for mutual benefits; and either through focused research centres or the efforts of individual researchers, exploring the dimensions of sustainable development and its achievement.[233] Thomas concludes that given the wide range of activities that take place at a university it is often a simple matter to focus the project on some aspect of the operations of the university. In these situations the university becomes an integral part of the learning experience for the students. There is also a direct local connection to their work, and from the university's perspective there is the probability of receiving knowledge and ideas about the campus that can assist present and future plans.[234]

3.2.7. Conclusion

In conclusion, there are a number of mechanisms, grouped under six themes – or 'elements', which could assist a department with the process of rapid curriculum renewal. Furthermore, there are three supporting mechanisms that might assist the process achieve a non-confrontational, pro-active and outcomes-based approach that preserves institutional diversity and innovation:

- External direction is also clearly important, to set the overarching timeframe for rapid curriculum renewal processes within the department.
- Leadership is clearly important, to build a strong collaborative foundation across campus and to make use of national and international collaboration with other academic institutions and non-profit organisations, to jointly deliver courses.
- An overarching strategic plan is needed, to identify the department's existing position and to set timeframes, responsibilities and resource requirements under clear stages or milestones.

These elements and supporting components are explored further among four other discipline examples in the next section.

3.3 Curriculum renewal experiences in non-engineering programs

Further to the review of engineering education literature, the question now asked of this review is, can the findings from the EESD literature be further informed by experiences from other disciplines that are similarly regulated?. In this section a review of experiences in four such disciplines is presented, including law, business, nursing, and medicine, where curriculum is observed to have undergone renewal in urgent and challenging times. For each discipline, a brief description of the context is provided, together with a summary of what was undertaken and lessons learned. Key mechanisms identified from the literature are summarised in tables, noting how the findings align with or add to the engineering literature findings.

3.3.1. Law curriculum – embedding skills training

Over the past several decades legal practice has been transformed by drivers such as globalisation, competitiveness and competition reform, information and communications technology, and by a determined move away from the adversarial system as the primary dispute resolution method.[235] In Australia, the 1994 Pearce Report on legal education found that, while many law faculties had made progress on earlier Pearce recommendations, crucially, there was still no blueprint or taxonomy for the development of skills programs within core curriculum.[236] In 2000 the Australian Law Reform Commission concluded that while the working environment of Australian lawyers had undergone dynamic change, there had been a critical and *'relative stasis in legal education, which appeared frozen in time'*.[237] Subsequently employers are demanding universities to develop generic skills, such as analysis, communication, team-work and leadership skills, around 'what lawyers need to be able to do', rather than the traditional focus of 'what lawyers need to know'.[238]

In a 2007 Carnegie report on educating lawyers, Sullivan *et al* reflected that efforts to improve legal education have been more piecemeal than comprehensive. Few schools had made the overall practices and effects of their educational effort a subject for serious study and few had attempted to systemically address inadequacies.[239] In a paper on meeting the needs of the 21st Century legal practitioner, Kift comments that while practice has changed radically:

> *'it is not clear that legal education reform has kept pace with the demands of modern practice … the content, methods and foci of legal knowledge are now also changing so rapidly that, in many areas of practice, the doctrinal law learnt at Law School is no longer current, even on graduation'.*[240]

Kift concludes that to ensure currency of legal education, the traditional law curriculum requires a fundamental re-conceptualisation to effectively prepare students for changing, challenging and globalised work environments – a view held by government, employers, professional associations, students and, in Australia, from universities themselves.[241] Kift subsequently describes the need for a 'blueprint or taxonomy' for a capability framework to guide innovative curriculum reform, where the curriculum response must be systematic, coherent and comprehensive.[242,243] A whole-of-program mapping process is now underway in almost every law school in Australia, whereby the discipline's desirable knowledge, skills and attitudes are mapped onto a matrix for multiple learning opportunities and contexts, which increase in complexity through the degree program, and where each individual unit or course within the program is then assessed for its contribution and subsequently iteratively reviewed for improvements.

Kift has led a process of rapid curriculum renewal now underway in the Queensland University of Technology's (QUT) Law School, where the task of identifying the capabilities required by and of QUT law graduates (and subsequent deconstruction into skills) took the faculty approximately six months. The process included:[244]

- Consultation with a variety of sources – i.e. seeking feedback from employers and graduates, and reviewing surveys produced by professional bodies, QUT's own university-wide list of graduate capabilities, and various international studies.
- Drafting several alternatives for discussion by stakeholders including staff, students, graduates, and employers (through staff meetings and focus groups) followed by review of the alternatives and resubmission for ultimate stakeholder agreement and adoption.
- Agreement on a set of capabilities - the sum of which was considered to describe satisfactorily a desirable graduate.
- The introduction of four new and integrated units in first year, which allowed the school to then take a whole of program approach to curriculum design, building incrementally on the first year foundation.

Further to this experience, the Australian Technology Network (of which QUT is a member university) has undertaken a major teaching and learning project on transferable 'graduate capabilities'. The initiative also situated the curriculum renewal process within a whole-of-university approach to systematic and explicit development of transferable skills between disciplines, taking advantage of existing institutional momentum and acceptance that change was already occurring.

From the above literature and in particular the QUT example detailed by Kift, a number of mechanisms were observed, as shown in Table 3-4.

Table 3-4. Observed mechanisms of rapid curriculum renewal in a law example

Observed Mechanisms	EESD elements
▪ *Consulting with staff, students and professional stakeholders regarding desired content within the curriculum*. This provides an immediate set of data which is based on the emerging consensus of the department's stakeholders.	✓ Awareness raising and developing a common understanding
▪ *Formal curriculum review to determine what should be taught*. This provides a common understanding among staff of what is being taught within the existing program.	✓ Awareness raising and developing a common understanding
▪ *Reviewing graduate capabilities and subsequent distillation of the capabilities and skills needed to describe a desirable graduate for the university*. This provides a common understanding among staff of the expectations for the curriculum.	✓ Identifying and mapping graduate attributes
▪ *Mapping the curriculum to the development of the desired graduate attributes*. This provides a clear rationale for subsequent curriculum renewal decisions, focusing on the program outcome rather than constraints provided by individual course politics.	✓ Identifying and mapping graduate attributes
▪ *Developing a customised first year.* This articulates 'up front' the type of program that is being offered, in consultation with students, staff and other stakeholders. This flagship approach to exposing students to key program goals quickly provides a solid foundation for subsequent curriculum renewal in other year levels.	✓ Content development and renewal (flagship and integrated courses)
▪ *Developing new and integrated courses which highlight the key desired graduate capabilities*. This provides supporting learning pathways for students who are being exposed to sustainability content in other flagship courses.	✓ Content development and renewal (flagship/ integrated courses)
▪ *Re-evaluating the validity and reliability of current assessment and feedback methods (alongside course development).* This provides a built-in reliable feedback loop which could be used to check progress in the future.	+ Content development and renewal (assessment design)
▪ *Using internal teaching and learning grants to undertake curriculum reviews, reviews of graduate capabilities and curriculum development*. This provides formal documentation of the process within existing budgetary frameworks, using existing grant mechanisms within the institution.	+ Campus integration (using existing frameworks and strategies)

Notes: '✓' denotes a mechanism that has already been observed from the review of engineering curriculum literature, while '+' indicates additional observations that could further enhance the description of the elements of rapid curriculum renewal.

3.3.2. Business curriculum – embedding corporate social responsibility

Although business is an established discipline in academia, it has faced significant critique over the last two decade on grounds including evaluation of teaching, learning, assessment, and training approaches as an urgent mandate.[245] As noted by Paton and Bevan, business and management schools have entered a period which can be described as one of 'disruptive transformation' where the sheer pace of change in business and management requires far more frequent and extensive changes in curricula - even calling into question much of what has traditionally been taught - putting pressure on procedures and processes developed in a more sedate era.[246] Within business curriculum, ethics and specifically corporate social responsibility (CSR), are key issues that have become touted as important ingredients in the business school curriculum.[247]

Leaders in business education are increasingly espousing the need for curriculum renewal to produce graduates who have the capacity to operate in an ethical and socially responsible manner. Acknowledgement that gaps need to be addressed is evident in initiatives such as the United Nations' Principles of Responsible Management Education (PRME),[248] and the 'Beyond Grey Pinstripes' biennial survey and ranking initiative, which assesses MBA programs internationally for their integration of social and environmental stewardship into curricula and research.[249] The debate is no longer about including sustainability content or not, but whether to integrate it, or have it as a special subject.

There was a scarcity of papers documenting actual experiences in business curriculum renewal, however, researchers such as Park have presented new models for business education which incorporate such content, claiming that current ways are 'denatured' and inappropriate. For example, Park's model is based on an integrated curriculum, with ethics being taught as part of a general business course, using systems thinking to develop moral imagination, strategic competence, ethical wisdom and courage.[250] Paton and Bevan also mention a profiling tool to assist strategic review in departments, programs and management schools, although literature on the use of this tool could not be found.[251] Matten and Moon[252] provide a summary of a 2003 survey of CSR education, including an account of the efforts that are being made to 'mainstream' CSR teaching and of the teaching methods deployed. The authors do not discuss a time imperative driving such renewal, but do use language that implies this when they conclude that a high percentage of respondents are aware of the imperative for mainstreaming CSR.

A notable discussion on rapid curriculum renewal was contained within a 2003 paper by Roper, Collins and Pratt,[253] discussing the progress of University of Waikato Management School, New Zealand. Subsequent to follow-up written communications with Professor Roper to clarify some details, the school's experience in addressing curriculum renewal in a timely manner is included in the following paragraphs.

The process of curriculum renewal to embed sustainability and corporate social responsibility content across undergraduate and post graduate teaching at Waikato Management School (WMS) has been ongoing since late 2002, including the appointment of Professor Roper as the Associate Dean of Sustainability in 2007. School wide consultation was undertaken, resulting in a collective decision to link the WMS mission statement with sustainability, although the decision was opposed by its Business Advisory Board at the time as they objected on the grounds that students would not want to study sustainability, and the business community would have no interest in such graduates. Roper noted that the fact that the current Board makes no such objections and is strongly supportive of such initiatives is indicative of the rapid shift that has taken place in the last 5 years towards greater concern and understanding of sustainability related issues, challenges and opportunities:

> *'Not all staff initially embraced the decision to integrate sustainability with their teaching, with some expressing concern that they would be 'forced' to change their teaching perspectives, and some were also concerned that they did not feel equipped to change. Because of the need to build capacity for sustainability teaching in each of the disciplines covered, and to avoid increasing any insecurities felt by staff, WMS began from the assumption that faculty research informs their teaching. To that end, incentives in the form of small grants or special conference travel allowances were awarded for sustainability related research projects. By 2007 there were more than 50 such projects engaged in by faculty and/or PhD students, with several of them representing collaborative efforts. Further, some of the projects had attracted external funding'.*[254]

The school used an audit process to assess courses as to how much sustainability content was already integrated into the curriculum. Roper reflects that the audit also served to test the theory of research informed teaching. While it was acknowledged that some staff had expanded their courses to include sustainability content without it being directly informed by their own research, the audit was useful in gauging faculty awareness of, and engagement with, the related issues. While conducting the audit, there was no attempt made to define 'sustainability' or 'business responsibility'. Rather, because conventional definitions can be within a differing context and scope, it was left

up to individual faculty members to come up with their own definitions by which to identify such course content. The audit process involved the Associate Dean of Sustainability asking each member of the staff to collate information in table form for their respective course/s, including such items as: the title of the course and course description; the subtopics taught within each course; and identification of those subtopics the teacher considered could be categorised as 'sustainability' and why.

The assessment found that sustainability was being integrated across much of the curriculum, however, the content was often not explicitly named and often not mentioned in the course documentation, making it difficult for courses across the program to support and enhance each other's material. The assessment also found that while the sustainability/social responsibility content was encouraging, clear gaps included areas such as carbon accounting and green supply chain management, where expertise is in high demand and is yet to be included in mainstream business education and hence is hard to find. According to Roper,[255] the school has since identified several steps to take involving prioritisation, and action. This includes activities such as: making adjustments to course titles and official descriptions to make the sustainability content more explicit; helping potential students in making their choices; supporting faculty to undertake relevant training; providing relevant teaching materials such as case studies; inviting experts to give training seminars; and hiring of staff with the required expertise. WSM intends to strategically invest in a mixture of all of these options over the next two years. The findings of the assessment undertaken by WSM will also be communicated to staff in a variety of ways including seminars to give an overview of the findings and to reiterate the purpose, especially for new staff members. Interviews with convenors of those courses which can be readily adapted, as described above, are being conducted to discuss what changes they might make and also to collect views on resource requirements.

Responding to such sentiments, the Asia Pacific Academy of Business in Society (APABIS) has been formed as a collaboration of several universities, corporations and NGOs in the Asia Pacific region, based at the Waikato Management School in New Zealand. APABIS provides a platform for business, NGOs, government departments, academia and other organisations to work innovatively and collaboratively toward sustainable development. In her role as founder and Director of APABIS, Roper reflected that the university's role is twofold: 1) to keep up-to-date with the latest opportunities to accelerate the transition to sustainable development; and 2) to produce graduates that are equipped to work in the new environment. This provides both a challenge and an opportunity for universities, which can be addressed through such collaboration with other education institutions, industry and government.[256]

In summary, the embedding of CSR into business education appears to be an ongoing process that has not yet reached systemic integration. Using the Waikato experience and the previously mentioned papers, the mechanisms in Table 3-5 were observed within the Business education experience.

Table 3-5. Observed mechanisms of rapid curriculum renewal in a business example

Observed Mechanisms	EESD elements
▪ *Incorporation of teaching strategies such as special seminars, CSR practitioner speakers, special events and conferences*. This improves awareness of CSR among staff and students, through internal capacity building.	✓ Awareness raising and developing a common understanding
▪ *Use of an initial audit in a collaborative manner with school staff.* This provides an assessment of where CSR content already exists within a given program, and what opportunities exist to increase such content throughout the program. As for the Law example, this helped raise awareness among the staff about upcoming plans.	✓ Curriculum auditing
▪ *Provision of optional modules on CSR to students within their existing curriculum* - This immediate implementation option is a relatively low cost approach as a temporary solution while more systemic integration proceeds.	✓ Content development and renewal (modules)
▪ *Embedding CSR into other modules and courses (in the form of examples, case studies, guest lecturers, and assessment considerations).* This provides consistency within the program with regard to language and focus.	✓ Content development and renewal (integration)
▪ *Involvement of industry through survey, advisory boards, and guest lectures*. This enables the university to keep up-to-date with industry expectations for graduate knowledge. As for the Law example, such consultation provided the process with a solid foundation.	✓ Outreach and bridging (industry)
▪ *Questioning of accreditation boards with regard to future accreditation requirements in CSR.* This provides clarification and hence significantly reduces the risk of not being aligned with student and industry expectations, and enables immediate action in curriculum renewal.	+ Outreach and bridging (accreditation)
▪ *Awarding of student scholarships.* This provides encouragement and increases enrolment in pioneering educational programs, as well as providing incentive to investigate offerings and to try the updated program.	+ Outreach and bridging (accreditation)

Notes: '✓' denotes a mechanism that has already been observed from the review of engineering curriculum literature, while '+' indicates additional observations that could further enhance the description of the elements of rapid curriculum renewal.

3.3.3. Nursing curriculum – embedding evidence-based practice

Given that a particular feature of the health profession is the continually compounding effects of change and pressures faced within the education and health sectors, examples from this industry are particularly pertinent. As described by Higgs and Edwards, allied health is a regular target of government and community scrutiny and funding restrictions, as well as being two areas in which the effects on people, individually and collectively, of current global forces, such as influenza pandemics, climate change and changes to health care, are profound.[257]

With the nursing curriculum largely governed by the requirements of professional and government bodies, there is constant pressure on nurse teachers and the whole structure of the curriculum, and the resultant adaptation of curricula, to take account of emerging perspectives and demands. Director for Professional Standards and Development for the UK Central Council for Nursing, Midwifery and Health, Peter Allan, reflected in 1987 that the curriculum is the result of both dynamic and complex changes, where the pace of change is often slow and seldom rapid, and where the major impetus for change has frequently been from outside the nursing profession.[258]

However, in a foreword to *The Curriculum in Nursing Education* (a guide to curriculum development), Perry reflected that the pace of change in nursing practice had accelerated over the previous decade, with contributing factors including the development of strategies to provide individualised care for patients, increased emphasis on the importance of building up a sound basis of knowledge for nursing care, advances in knowledge and technology, the emerging role of the nurse in comparison to other healthcare workers, and changing societal demands and expectations.[259] In particular, nurse teachers, at all levels, have their own special part to play during this challenging time, where those in daily contact with learners in classrooms or practice areas have no less important a contribution to make than heads of schools and leaders in nursing education, and it is vital that all are properly equipped to co-operate.

Within nursing curriculum, the issue of embedding 'evidence-based practice' (EBP) into the curriculum has been a key one over the last decade.[260,261,262,263,264] While EBP related curricula exists, Australian researcher Chaboyer concludes that there has been limited discussion of EBP as an educational paradigm, and therefore its inclusion as a standard in nursing curricula has been limited.[265,266,267] In a 2005 nursing textbook on *Teaching Evidence-Based Practice in Nursing,* researchers Levin and Fieldman demonstrate how the nursing field is now addressing embedding evidence-based practice (EBP) as a major curriculum renewal effort, including some guidance on timely

implementation.[268] In presenting a number of strategies for teaching EBP the publication does not explicitly address the issue of urgent implementation, however, the foreword writer notes that it will likely play an important role in accelerating the paradigm shift to EBP that will lead to a higher quality of care being delivered by healthcare professionals.[269]

Researcher Susan Docking has explored issues involved in curriculum innovation in nursing, highlighting the need for the establishment to inject resources so that curriculum innovation can be planned and implemented at the same time existing arrangements are being maintained, as major curriculum change requires long-term planning and may take upwards of five years or more to be realised.[270] She notes that curriculum innovation planning must be staged, with the long-term finished product clearly identified at the beginning, and she identifies a number of questions that the person or group initiating the change should ask:[271]

- *'What is the change aiming to do?*
- *Does it affect the whole or a part of the curriculum?*
- *What will the staff see as the advantages/ disadvantages?*
- *How complex is it to understand and use?*
- *Is the innovation compatible with existing values and practices?'*

Chaboyer and other authors also caution that for most higher education programs, in both Australia and internationally, curriculum change is a slow process that requires significant planning and involves high levels of co-operation between academic staff.[272,273,274,275,276] It may be relatively easy to integrate a research thread into curriculum, for example, with research articles in clinical orientated courses. However, it may be more difficult to rewrite whole curriculum to ensure that a research subject is taught very early in the program. Hence, the information that emerges from such a project must be tailored to the local context within which it is to be used.

However, there are signs of progress. For example, In the New York University's Division of Nursing for example, in the first year of the curriculum renewal process, management undertook bimonthly meetings and faculty development workshops which involved local and invited international EBP experts. As part of the strategic process of curriculum renewal, the Division replaced a statistics course with another that enhanced EBP learning.

From these curriculum renewal experiences in nursing education, a number of mechanisms were evident as shown in Table 3-6, which appeared to have assisted

sector-wide integration of evidence-based practice; a complex shift in the curriculum which needed to be undertaken in a short period of time.

Table 3-6. Observed mechanisms of rapid curriculum renewal in a nursing example

Observed Mechanisms	EESD elements
▪ *The use of scoping workshops involving some or all faculty staff.* This provided a consensus on the need for transformational curriculum renewal so that graduates would be prepared to assume leadership roles.	✓ Awareness raising and developing a common understanding
▪ *Ongoing professional development among staff and support staff (e.g. librarians).* This assists in maintaining a culture of continual learning and curriculum renewal.	✓ Awareness raising and developing a common understanding
▪ *Initial evaluation of a Department's position.* This was undertaken through a preliminary review of literature and an internal review of existing program capabilities within the school.	+ Awareness raising and developing a common understanding (situational analysis)
▪ *The utility of benchmarking.* This enables the identification of innovative practices that may be used to embed new content into curricula.	+ Awareness raising and developing a common understanding (benchmarking)
▪ *Identification through concept mapping.* This provides an idea of the extent to which courses in the curriculum (i.e. description, outcomes, assignments) are using theory and research in practice.	✓ Identifying and mapping graduate attributes
▪ *Targeting new content for specific courses in the core, advanced practice core, and specialty component courses.* This may involve swapping content within courses, or replacing old courses with new ones.	✓ Content development and renewal (content integration)
▪ *The use of modular material online.* This is a useful mechanism for students to access content when they are on or off campus, in addition to providing an efficient mechanism for updating content (i.e. without printing and distribution constraints).	✓ Content development (online material)
▪ *Monitoring all courses in the program for successful integration of new content.* This provides a review of faculty and student competencies as well as teaching strategies.	+ Content development and renewal (evaluation)

Notes: '✓' denotes a mechanism that has already been observed from the review of engineering curriculum literature, while '+' indicates additional observations that could further enhance the description of the elements of rapid curriculum renewal.

3.3.4. Medicine curriculum – embedding technological advances

Since the turn of the century in particular, there has been increasing attention paid to medical education literature regarding the global need for medical education to

embrace technology. In a 2000 article on 'Communication and Information Technology in Medical Education', authors Ward *et al* comment that the 1990s saw rapid advances in communication and information technology (C&IT), and the pervasion of the worldwide web into everyday life, which has important implications for education. Within less than two student generations, C&IT has been repositioned as an integral component of the medical school environment.[277] However, the authors cautioned that although C&IT can provide powerful tools for learning and teaching in medicine, altering the way the subject is taught, the pace of technological development and the drive to incorporate such technologies into the curriculum threatens to outstrip understanding of how they can be used most effectively, indeed the ability of our teachers to use them at all. The authors conclude that if this is to be avoided, educators must proceed on a firm basis of educationally sound design, rigorous evaluation of educational cost-effectiveness, and, above all, provision of adequate training for teaching staff.[278]

A 2008 European Commission survey of 7,000 practitioners about e-health in Europe noted that Doctors not using ICT cite a lack of training and technical support as major barriers. To spread e-health, survey participants recommended more ICT in medical education, more training and better electronic networking among healthcare practitioners wanting to share clinical information.[279]

A review of medical education literature indicates that the medical education field has a very engaged and proactive approach towards the process of curriculum renewal, with frequent communication from professional bodies and senior management. Indeed the World Federation of Medical Education in 2001 published guidelines for using information technology in medical education.[280] In his paper on 'Curriculum development in medical education: From acronyms to dynamism', Prideaux summarises the history of the dynamic nature of medical education where the field has been active in considering curriculum renewal based on a variety of emergent models. Prideaux notes that medical education is a rapidly expanding discipline with its practitioners drawn from a mix of backgrounds. Among them there is an increased understanding of the centrality of the curriculum process in the translation of educational ideas in practice.[281] Prideaux identifies four main trends that underlie this increased understanding: a widened conception of the major elements of curriculum and their interactivity; a more conceptual and global view of curriculum; the incorporation of ideas from the educational literature; and the need for a dynamic overarching model of curriculum. Indeed, medical education is historically responsible for generating educational strategies such as Problem Based Learning in the early

1960s, and later 'Objective Structured Clinical Examination' (OSCE) in the late 1970s.[282]

Recent examples of the dynamic nature of medical education and curriculum renewal include:

- Johns Hopkins University School of Medicine - began with a comprehensive website (LectureLinks) for the curriculum within the first year that the internet was widely deployed.[283]
- Stanford University - where the curriculum renewal process, beginning in 2002, led with a clear message from the Dean, outlining the principles for the curriculum renewal process and inviting the readership to a presentation. The Dean's message concludes with, *'I am excited by the progress that has been made and do very much believe that we have the opportunity to develop a revitalized learning environment for our students and faculty that will impact on generations of future Stanford Medical Students. I want to add my personal commitment to affirming the importance of this process and the need for the current momentum to be sustained and enhanced during the months ahead*.'[284]
- SUNY Downstate College of Medicine in Brooklyn, New York - currently undergoing a curriculum renewal program to establish a new undergraduate medical curriculum in the fall, 2011.[285] The school has a website page dedicated to curriculum renewal, with a recorded message from the Dean. According to the School's Dean Professor Ian Taylor, *'It has been 10 years since we looked at our curriculum. Much has changed in those 10 years and there are many changes on the horizon. As such, it appears timely to review our curriculum to ensure we are well positioned for these changes … Technology is causing a revolution in teaching and in medicine. Computers and hand-held devices are now intrinsic to learning and health care, and we need to evaluate where technology fits in our curriculum now and into the future … The skill in reviewing the curriculum is to preserve what makes us unique while ensuring a quality education for our students … I have no doubt that this review process will make us a better and an even more attractive school for students to apply to'.*[286]
- An online resource for systematic curriculum renewal - supported in part through a 'Faculty Development Program in General Internal Medicine' grant at Johns Hopkins University.[287] The resource includes a stepwise approach to curriculum development which,

'does not always follow one another in sequence, but does constitute a dynamic, interactive and systematic process… no step is more important than the first, the general needs assessment (GNA) … When completed, the GNA makes a strong argument for the need for the curriculum, sets the stage for the generalizability of the curriculum, and identifies potential educational research questions'.

As Thomas and Kern note, previously developed and/or validated methods and curricula are identified as part of the development of such material, to inform efforts and prevent duplication of work. A well-researched first step can positively impact on steps beyond the learner objectives, by identifying educational methodologies, faculty development resources, potential funding resources, and opportunities for disseminating the curriculum.[288]

From a review of the above literature in the field of medical education, the following mechanisms emerged as possible aids to curriculum renewal in urgent and challenging times, as shown in Table 3-7.

Table 3-7. Observed mechanisms of rapid curriculum renewal in a medicine example

Observed Mechanisms	EESD elements
▪ *Public statements from senior management on the curriculum renewal process.* This tracks the progress of curriculum renewal and makes information available to staff, students and the local community, an example of which is the use of a publically available website.	+ Awareness raising and developing a common understanding (communication of progress)
▪ *An initial general needs assessment.* This defines the deficits in knowledge, attitude, or skills that currently exist in practitioners, and the ideal approach to teaching and learning these objectives.	+ Awareness raising and developing a common understanding (situational analysis)
▪ *The generation of supporting resources for academics.* This provides access to curriculum renewal material, both for the process of curriculum renewal and for the content itself.	✓ Content development (modular material)
▪ *The use of online interactive medical learning tools.* This provides an opportunity for students to learn on and off campus, in addition to facilitating efficient updating of content (as also highlighted in the nursing example).	✓ Content development (online material)

Notes: '✓' denotes a mechanism that has already been observed from the review of engineering curriculum literature, while '+' indicates additional observations that could further enhance the description of the elements of rapid curriculum renewal.

3.3.5. Conclusion

It is concluded from the review of four non-engineering examples that there are strong similarities among the processes observed in EESD literature, namely:

- Awareness raising and developing a common understanding - All of the examples used awareness raising activities with staff in an effort to develop an appreciation among faculty for the need for change within the curriculum, and the need for change within a brief period of time. The departments also gathered information about the new knowledge and/or skills with regard to legislative, regulatory, professional and program accreditation requirements, which appears to be an important activity at the departmental level.
- Identifying and mapping graduate attributes - All of the examples used interaction with key staff (for example through workshops and meetings) to define for the department what it is about the new knowledge and/or skills that is important for the students to learn. Most of the examples sought to gain a detailed understanding of how the new knowledge/ skills could be integrated within the existing program – i.e. what are the specific components that can be taught? And where should they be taught? This involved mapping the knowledge/ skills within the program.
- Curriculum auditing – The business example highlighted auditing of course outlines and assessment materials as a mechanism to quickly identify where the program strengths and weaknesses are with regard to existing coverage of the knowledge/ skills, and then future review of how well the process is proceeding.
- Content development and renewal - The examples highlighted a variety of actions for implementing the curriculum renewal process, from flagship style courses that highlighted the new knowledge/ skills at various stages in the program (from first year through to final year of study), to peppering the program with components of the new knowledge/ skills. There appears to be a mixture of new course development, and existing course renewal, with a gradual flow-on of content through the curriculum.
- Bridging and outreach - The examples also highlighted the importance of involving employers, to ensure that the new knowledge/skills would be incorporated in students' education in a manner attractive to employers. Some mentioned the potential of offering short courses as professional development, as a way to introduce the new knowledge/ skills in the workplace more quickly.
- Campus integration: The examples did not mention the role of campus integration with regard to onsite applications, which is reasonable considering the service-

oriented nature of the professional programs considered, in contrast to the infrastructure and product design and construction opportunities available in engineering. However, there was mention of fitting in with existing curriculum renewal or other change programs on campus.

Furthermore, there are additional mechanisms discussed in the literature for other discipline areas, which can help to inform the elements of curriculum renewal distilled from the engineering education literature (highlighted in the previous four tables):

- *Awareness raising and developing a common understanding – communication of progress:* Including regular and public statements from senior management on how the curriculum renewal process is proceeding, to raise awareness of the initiative amongst staff, students and the local community.
- *Awareness raising and developing a common understanding – situational analysis:* Incorporating an initial investigation of the department's position with regard to the new content area being considered for integration, practitioner needs, and existing strengths within the school to teach such content. This could include a preliminary literature review in addition to an internal review of existing program capabilities.
- *Awareness raising and developing a common understanding – benchmarking:* Including a benchmarking analysis of competitors in the emerging content area, in addition to identifying innovative practices that may be used to embed the new content into curricula.
- *Content development and renewal - evaluation:* Incorporating the evaluation of assessment and feedback methods (alongside course development and renewal), to provide a reliable feedback loop which can be used to monitor progress.
- *Outreach and bridging – accreditation feedback:* Seeking feedback from accreditation bodies with regard to future accreditation requirements and the timeframe for such requirements, to reduce accreditation risks.
- *Outreach and bridging – scholarships:* Offering scholarships to potential students, to encourage enrolment in pioneering educational programs, or updated programs.
- *Campus integration – access to funding:* Harnessing existing frameworks and strategies being implemented within the institution, to access funding for rapid curriculum renewal activities such as curriculum reviews, graduate attribute mapping and curriculum development.

3.4 Conclusion

It is concluded from the literature review that 20th Century curriculum renewal was largely incremental and marginal over extended periods, rather than transformative over time-constrained periods. While many authors have commented on the slow nature of curriculum for the last half century (as documented by Heywood[289]), there is an absence of literature addressing how the process may be accelerated. There is also a distinct lack of discourse about how to address an apparent time lag between emerging information and subsequent integration of new knowledge and skills into the curriculum.

The three core elements observed to be informing curriculum renewal are focused on the issues of systematic curriculum design and development comprising 'understanding the purpose of the curriculum', 'identifying knowledge and teaching methods', and 'undertaking processes for monitoring and evaluation'. Three component phases of curriculum renewal were also observed, including *ad hoc* renewal, flagship renewal and integration. However, while these aspects of curriculum renewal provide significant guidance on systematic curriculum construction, they focus on the content, educational experience and pedagogy of curriculum renewal, and do not consider timing, or implications of constrained timeframes for curriculum construction, implementation or review. Furthermore, there are no existing models to guide curriculum renewal processes affected by short time-constraints.

Considering the findings of Chapter 1, the core issue is that the usual or 'standard' timeframe to update curriculum for professional disciplines may be too long to meet changing market and regulatory requirements for emerging knowledge and skills. It is concluded that the challenge is how to accelerate these phases to produce graduate students within the next decade who have been exposed to engineering education for sustainable development (EESD), ideally over 6-8 years.

From a review of EESD literature, a number of mechanisms were observed to be informing a process of rapid curriculum renewal. These mechanisms were grouped into six elements of curriculum renewal: awareness raising and developing a common understanding; identifying and mapping graduate attributes; curriculum auditing; content development and renewal; bridging and outreach; and campus integration.

Strong similarities were observed between the use of these elements within engineering education and other strongly regulated disciplines such as law, business, nursing and medicine, with the exception of the element 'campus integration'. However

the non-engineering literature did contain reference to the need to fit within existing curriculum renewal or other change programs underway on campus.

Figure 3-6 is a stylistic representation of how the elements listed above complement existing documentation-focused elements evident in the curriculum renewal literature.

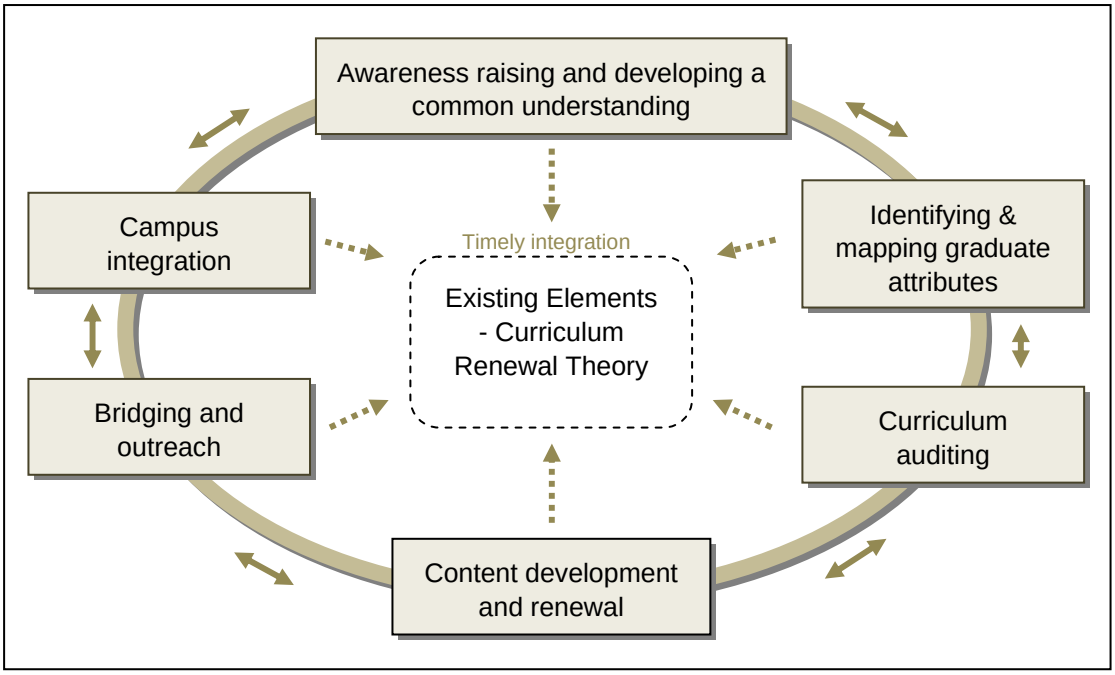

Figure 3-6. Stylistic representation of relationships between elements supporting rapid curriculum renewal and existing curriculum renewal theory

However, while these elements of curriculum renewal have the potential to influence the pace of change, it is concluded from the investigation that these elements do not themselves create a time imperative; they are not accelerating mechanisms. For example, even in urgent and challenging times, without a clear time imperative, raising awareness and developing a common understanding among staff could theoretically still stretch over many years. Likewise activities such as graduate attribute mapping, curriculum auditing and course development could all proceed systematically, but relatively slowly.

Hence, in addition to these elements, a time constraint also needs to be present, within which the elements can then be strategically implemented to support rapid curriculum renewal. Furthermore, the review of engineering education literature and other discipline examples also highlighted the role of a range of catalysts in setting the timeframe for accelerated curriculum renewal, the need for leadership throughout the process, and strategic planning to optimise the usefulness of the elements of curriculum renewal. These conclusions are explored further in Chapter 4 through the process of reflexive inquiry, and in Chapter 5 through formal peer review.

References

[1] Gordon, P. and Lawton, D. (1978) *Curriculum Change in the Nineteenth and Twentieth Centuries*, SevenOaks, Kent, Hodder & Stoughton Educational.

[2] Brownell, J. and Scarino, A. (1993) *Theoretical Bases of the Proposed Target-Oriented Curriculum (TOC) Framework*, Hong Kong, Institute of Language in Education, Education Department.

[3] Barnett, R. and Coate, K. (2006) *Engaging the Curriculum in Higher Education*, The Society for Research into Higher Education, Open University Press, England, p6.

[4] Smith, D. and Lovatt, T. (1990) *Curriculum: Action on reflection*, Social Science Press Wentworth Falls, NSW, cited in Billet, S. and Stevens, J. (2007) 'Study Guide', *4141/8144VTA Curriculum Development in Adult and Vocational Education*, Griffith University.

[5] James, R. (2002) 'Students' Changing Expectations of Higher Education and the Consequences of Mismatches with Reality', in OECD, *Responding to Student Expectations*, OECD, Paris.

[6] Meyers, N. and Whelan, K. (2004) 'Enhancing the transition of first year science students – a strategic and systematic approach', First Year in Higher Education Conference 2004, Monash University, Melbourne, p2.

[7] Hall, S. (1996) 'Action research for institutional curriculum change. Different Approaches: Theory and Practice in Higher Education', HERDSA Conference, Perth.

[8] Glatthorn, A. (1987) *Curriculum Leadership*, Scott Foresham, Illinois, summarised by Print, M. (1993) *Curriculum Development and Design*, 2nd ed. Allen & Unwin, Sydney, cited in Billet, S. and Stevens, J. (2007) 'Study Guide', *4141/8144VTA Curriculum Development in Adult and Vocational Education*, Griffith University.

[9] Print, M. (1993) *Curriculum Development and Design*, 2nd ed., Allen & Unwin, Sydney, pp5-7 cited in Billet, S. and Stevens, J. (2007) 'Study Guide', *4141/8144VTA Curriculum Development in Adult and Vocational Education*, Griffith University.

[10] Billet, S. and Stevens, J. (2007) 'Study Guide', *4141/8144VTA Curriculum Development in Adult and Vocational Education*, Griffith University.

[11] Stenhouse, L. (1975) *An introduction to Curriculum Research and Development*, Heineman, London, pp4-5.

[12] Egan, K. (1978) 'What is Curriculum?' *Curriculum Inquiry*, vol 8, no1, pp66-72.

[13] Egan, K. (1978) 'What is Curriculum?' *Curriculum Inquiry*, vol 8, no1, pp66-72, www.blackwellpublishers.co.uk/asp/jOURNAL.ASP?REF=0362-6784, accessed 11 November 2009.

[14] Pinar, W. (2004) *What is Curriculum Theory?* Lawrence Erlbaum, New Jersey.

[15] Print, M. (1993) *Curriculum Development and Design*, 2nd ed., Allen & Unwin, Sydney.

[16] Stenhouse, L. (1975) *An introduction to Curriculum Research and Development*, Heineman, London.

[17] Taba, H. (1962) *Curriculum Development: Theory and Practice*, p448.

[18] Marsh, C. (2004) *Key Concepts for Understanding Curriculum,* 3rd Edition, Routledge, New York.

[19] Kift, S. (2008) '21st Century Climate for Change: Curriculum Design for Quality Learning Engagement in Law', *Legal Education Review*, vol 18, no 1 & 2, Australia, p1.

[20] Taba, H. (1962) *Curriculum Development: Theory and Practice*, Harcourt Brace and World, New York, p448-449.

[21] Centre for Educational Research and Innovation (1998) *Making the Curriculum Work*, Organisation for Economic and Co-operative Development (OECD), p12, www.mszs.si/eurydice/pub/oecd/kurikulum.pdf, accessed 13 June 2009.

[22] Beavis, C. (1997) 'Lovely Literature: Teacher Subjectivity and Curriculum Change', 1997 AARE Conference. Brisbane, The Australian Association for Research in Education.

[23] Bobbitt, F. (1971) *The Curriculum*, Houghton Mifflin, Boston, Preface.

[24] Wilkinson, J. (2002) 'Re-engineering competency-based education through the use of a multimedia CDROM: A matter of life or death', *Industry and Higher Education*, vol 16, no 4, pp261-265.

[25] Dempster, N. (2009) Personal communications, Professor Neil Dempster, School of Education, Griffith University, 13 February 2009.

[26] Whitfield, R. (1978) 'The Changing School Curriculum in Europe', *Paedagogica Europaea*, vol 6, Blackwell Publishing, pp 107-118.

[27] Whitfield, R. (1978) 'The Changing School Curriculum in Europe', *Paedagogica Europaea*, vol 6, Blackwell Publishing, pp 114.

[28] Whitfield, R. (1978) 'The Changing School Curriculum in Europe', *Paedagogica Europaea*, vol 6, Blackwell Publishing, pp 116.

[29] Egan, K. (1978) 'What is Curriculum?' *Curriculum Inquiry*, vol 8, no 1, pp66-72.

[30] Kerr, J. (1968) *Changing the Curriculum*, Unibooks, University of London Press Ltd, p37.

[31] Kerr, J. (1968) *Changing the Curriculum*, Unibooks, University of London Press Ltd, p7-8.

[32] UNESCO (1991) *World Education Report 1991*, UNESCO, Paris.

[33] Kennedy, K. (1995) 'An analysis of the policy context of recent curriculum reform efforts in Australia, Great Britain and the US', in Carter, D.S.G. and O'Neill, M. (eds) *International Perspectives on Educational Reform and Policy Implementation*, Falmer Press, London, citing Coombs, P. (1985) *The World Crisis in Education: The View from the Eighties*, Oxford University Press, Oxford, p9.

[34] Fien, J. (2001) 'Education for sustainability: Reorienting Australian schools for a sustainable future', *Tela: Environment, Economy and Society*, Issue 8, Australian Conservation Foundation, www.acfonline.org.au/uploads/res/res_tp008.pdf, accessed 21 December 2009.

[35] Ministerial Council on Education, Employment, Training and Youth Affairs (2008) *Melbourne Declaration on Educational Goals for Young Australians*, Government Printing Office, Canberra.

[36] Australian Curriculum, Assessment and Reporting Authority (ACARA) (2009) 'Australian Curriculum', http://www.acara.edu.au/curriculum.html, accessed 21 December 2009.

[37] Ministerial Council on Education, Employment, Training and Youth Affairs (1988) *Melbourne Declaration on Schooling*, 5 December, Government Printing Office, Canberra.

[38] Ministerial Council on Education, Employment, Training and Youth Affairs (1999) *Adelaide Declaration on National Goals for Schooling in the Twenty-First Century*, Government Printing Office, Canberra.

[39] Ministerial Council on Education, Employment, Training and Youth Affairs (2008) *Melbourne Declaration on Educational Goals for Young Australians*, Government Printing Office, Canberra.

[40] Singh, P. (2008) 'The Importance of a National Curriculum', *Opinion and Analysis, ABC Net*, 5 May 2008, http://www.abc.net.au/news/stories/2008/05/05/2235057.htm, accessed 21 December 2009.

[41] Bullen, F., Waters, D., Bullen, M. and de la Barra, B. (2004) 'Incorporating and developing graduate attributes via program design', in Snook, C. and Thorpe, D. (eds) '15th Annual AAEE Conference', Australasian Association for Engineering Education, Toowoomba, Australia, pp29–39.

[42] Roberts, D. (1997) 'Flexible learning and the paradigm shift', *Synergy*, Issue 6, Centre for Teaching and Learning, University of Sydney, p3, cited in Higgs, J. and Edwards, H. (1999) *Educating Beginning Practitioners,* Butterworth-Heinmann Ltd, London, p3.

[43] Barnet, R., and Coate, K. (2006) *Engaging the Curriculum in Higher Education*, The Society for Research into Higher Education, Open University Press, England, p7,9.

[44] Fullan, M. (1982) *The Meaning of Educational Change*, Teachers College Press, Columbia University, p91, cited in Billet, S. and Stevens, J. (2007) 'Study Guide', *4141/8144VTA Curriculum Development in Adult and Vocational Education*, Griffith University, Brisbane.

[45] Billet, S. and Stevens, J. (2007) 'Study Guide', *4141/8144VTA Curriculum Development in Adult and Vocational Education*, Griffith University.

[46] Howard, J. (2007) *Curriculum Development,* Department of Education, Elon University, p6, http://org.elon.edu/catl/documents/curriculum%20development.pdf, accessed 12 April 2009.

[47] Barnet, R. and Coate, K. (2006) *Engaging the Curriculum in Higher Education*, The Society for Research into Higher Education, Open University Press, England

[48] Heywood, J. (2005) *Engineering Education Research and Development in Curriculum and Instruction*, Institute of Electrical and Electronics Engineers (IEEE), Inc.

[49] Coaldrake, P. and Stedman, L. (1999) *Academic Work in the Twenty-first Century Changing Roles and Policies*, DEST Occasional Paper Series 99-H, p13, www.dest.gov.au/highered/occpaper.htm, accessed 5 February 2010.

[50] James, R. (2002) '"Students' Changing Expectations of Higher Education and the Consequences of Mismatches with the Reality'" in OECD, *Responding to Student Expectations*, OECD, p81.

[51] Herrick, V. and Tyler, R. (1950) *Toward Improved Curriculum Theory,* Supplementary Educational Monography, no 71, University of Chicago Press, p64, cited in Taba, H. (1962) *Curriculum Development: Theory and Practice*, Harcourt Brace and World, New York, p422.

[52] Taba, H. (1962) *Curriculum Development: Theory and Practice*, Harcourt Brace and World, New York, p422.

[53] Tyler, R. (1949) *Basic Principles of Curriculum and Instruction*, University of Chicago Press, Chicago.

[54] Taba, H. (1962) *Curriculum Development: Theory and Practice*, Harcourt Brace and World, New York.

[55] Bobbitt, F. (1971) *The Curriculum*, Houghton Mifflin, Boston.

[56] Stenhouse, L. (1975) *An Introduction to Curriculum Research and Development*, Heineman, London.

[57] MacDonald, B. and Walker, R. (1976) *Changing the Curriculum*, Open Books Publishing Limited, London.

[58] Grundy, S. (1987) *Curriculum: Product or Praxis?,* Falmer Press, Lewes.

[59] Cornbleth, C. (1990) *Curriculum in Context*, Falmer Press, Basingstoke.

[60] Marsh, C. (2004) *Key concepts for understanding curriculum,* 3rd Edition, Routledge, New York.

[61] Eraut, M. (1976) 'Some perspectives on curriculum development in teacher education', *Education for Teaching*, vol 99, pp11–21.

[62] Grundy, S. (1987) *Curriculum: Product or Praxis*, The Falmer Press, Deakin Studies in Education Series, p1.

[63] Brady, L. (1995) *Curriculum development*, 5th Edition, Prentice Hall, New York.

[64] Blenkin, G., Edwards, T. and Kelly, A. (1992) *Change and the Curriculum*, Paul Chapman, London, p23.

[65] Smith, M.K. (2000) 'Curriculum theory and practice', *The Encyclopaedia of Informal Education*, www.infed.org/biblio/b-curric.htm, accessed 12 June 2009.

[66] Franklin, B. (undated) 'Education Encyclopedia: Franklin Bobbitt', answers.com, www.answers.com/topic/franklin-bobbitt, accessed 12 June 2009.

[67] Bobbitt, F. (1918) *Curriculum*, Houghton Mifflin, Boston.

[68] Bobbitt, F. (1924) *How to Make a Curriculum*, Houghton Mifflin, Boston.

[69] Tyler, R.W. (1949) *Basic Principles of Curriculum and Instruction*, University of Chicago Press, Chicago.

[70] Howard, J. (2007) *Curriculum Development,* Department of Education, Elon University, http://org.elon.edu/catl/documents/curriculum%20development.pdf, accessed 12 April 2009.

[71] Stenhouse, L. (1975) *An introduction to Curriculum Research and Development*, Heineman London.

[72] Cornbleth, C. (1990) *Curriculum in Context,* Falmer Press, Basingstoke.

[73] Nicholls, A. and Nicholls, A. (1978) *Developing a curriculum: a practical guide*, Allen and Unwin, London, cited in Billet, S. and Stevens, J. (2007) 'Study Guide', *4141/8144VTA Curriculum Development in Adult and Vocational Education*, Griffith University, Brisbane, p73.

[74] Nicholls, A. and Nicholls, A. (1978) *Developing a curriculum: a practical guide*, Allen and Unwin, London.

[75] Billet, S. and Stevens, J. (2007) 'Study Guide', *4141/8144VTA Curriculum Development in Adult and Vocational Education*, Griffith University, Brisbane, p73

[76] Stenhouse, L. (1975) *An introduction to Curriculum Research and Development*, Heineman Educational, London, p11.

[77] Howard, J. (2007) *Curriculum Development* Department of Education, Elon University, http://org.elon.edu/catl/documents/curriculum%20development.pdf, accessed 12 April 2009.

[78] Taba, H. (1962) *Curriculum Development: Theory and practice*, Harcourt Brace and World, New York.

[79] Smith, M.K. (2000) 'Curriculum theory and practice', *The Encyclopaedia of Informal Education*, www.infed.org/biblio/b-curric.htm, accessed 12 June 2009.

[80] Brady, L. (1995) *Curriculum Development*, 5th Edition, Prentice Hall, New York, pp74-76.

[81] Brady, L. (1995) *Curriculum Development*, 5th Edition, Prentice Hall, New York.

[82] Grundy, S. (1987) *Curriculum: Product or Praxis?*, Falmer Press, Lewes.

[83] Grundy, S. (1987) *Curriculum: Product or Praxis?*, Falmer Press, Lewes, p115.

[84] Print, M. (1993) *Curriculum Development and Design*, 2nd Edition, Allen & Unwin, Sydney.

[85] Smith, M.K. (2000) 'Curriculum theory and practice', *The Encyclopaedia of Informal Education*, www.infed.org/biblio/b-curric.htm, accessed 12 June 2009.

[86] Stenhouse, L. (1975) *An Introduction to Curriculum Research and Development*, Heineman Educational, London.

[87] Grundy, S. (1987) *Curriculum: Product or Praxis?*, Falmer Press, Lewes.

[88] Dewey, J. (1938) *Experience and Education*, Macmillan, New York.

[89] Jackson, P. (1968) *Life in Classrooms*, Holt, Rinehart & Winston, New York.

[90] Reynolds, J. and Skilbeck, M. (1976) *Culture in the Classroom,* Open Books, London.

[91] Cornbleth, C. (1990) *Curriculum in Context*, Falmer Press, Basingstoke, p5.

[92] Howard, J. (2007) *Curriculum Development,* Department of Education, Elon University, http://org.elon.edu/catl/documents/curriculum%20development.pdf, accessed 12 April 2009.

[93] Knight, P.T. (2001) 'Complexity and curriculum: A process approach to curriculum-making', *Teaching in Higher Education*, vol 6, Issue 3, pp369-381.

[94] Barnett, R., Parry, G. and Coate, K. (2001) 'Conceptualising curriculum change', *Teaching in Higher Education*, vol 6, Issue 4, pp435-449.

[95] Parker, J. (2003) 'Reconceptualising the curriculum: from commodification to transformation', *Teaching in Higher Education*, vol 8, Issue 4, pp529-543.

[96] Parker, J. (2003) 'Reconceptualising the curriculum: from commodification to transformation', *Teaching in Higher Education*, vol 8, Issue 4, pp529-543.

[97] Fink, L. (2007) 'The Power of Course Design to Increase Student Engagement and Learning', *PeerReview - Analysis*, *Association of American Colleges and Universities*, Winter 2007, http://aacu-secure.nisgroup.com/peerreview/pr-wi07/documents/PRWI07_fink.pdf, accessed 12 April 2009.

[98] Fink, L. (2003) *Creating significant learning experiences: an integrated approach to designing college courses*, Jossey-Bass, San Francisco.

[99] Wiggins, G. and McTighe, J. (2005) *Understanding by Design,* Expanded 2nd Edition, Association for Supervision and Curriculum Development, Alexandria, Virginia.

[100] Fink, L. (2007) 'The Power of Course Design to Increase Student Engagement and Learning', *PeerReview - Analysis*, *Association of American Colleges and Universities*, Winter 2007, http://aacu-secure.nisgroup.com/peerreview/pr-wi07/documents/PRWI07_fink.pdf, accessed 12 April 2009, p13.

[101] Bloom, B. (ed) (1956) *Taxonomy of Educational Objectives. The classification of Educational Goals, Handbook I: Cognitive Domain*, David McKay, New York.

[102] Wiggins, G. and McTighe, J. (2005) *Understanding by Design,* Expanded 2nd Edition, Association for Supervision and Curriculum Development, Alexandria, Virginia, pp10-11.

[103] Wiggins, G. and McTighe, J. (2005) *Understanding by Design,* Expanded 2nd Edition, Association for Supervision and Curriculum Development, Alexandria, Virginia, p13.

[104] Stephen, W. (1996) 'National and global imperatives in engineering education', *Australasian Journal of Engineering Education*, vol 7, no 1.

[105] Heywood, J. (2005) *Engineering Education Research and Development in Curriculum and Instruction*, Institute of Electrical and Electronics Engineers (IEEE), p459.

[106] Heywood, J. (2005) *Engineering Education Research and Development in Curriculum and Instruction*, Institute of Electrical and Electronics Engineers (IEEE), p177.

[107] Heywood, J. (2005) *Engineering Education Research and Development in Curriculum and Instruction*, Institute of Electrical and Electronics Engineers (IEEE), pp5-6.

[108] Wulf, W. (1998) 'The Urgency of Engineering Education Reform', *The Bridge - Frontiers of Engineering*, vol 28, no 1, www.nae.edu/nae/bridgecom.nsf/weblinks/NAEW-4NHMKV?OpenDocument, accessed 9 April 2009.

[109] Wulf, W. (2002) 'The Urgency of Engineering Education Reform', excerpts from the Laboratory for Innovative Engineering Education 2002 Distinguished Lecture, Auburn University, AL March 22, 2002, 3/3&4 July-December 2002

[110] Wulf, W. (2002) 'The Urgency of Engineering Education Reform', excerpts from the Laboratory for Innovative Technology and Engineering Education 2002 Distinguished Lecture. 3/3&4 July- December 2002.

[111] Wulf, W. (1998) 'The Urgency of Engineering Education Reform', *The Bridge – Frontiers of Engineering,* vol 28, no 1, http://www.nae.edu/nae/bridgecom.nsf/weblinks/NAEW-4NHMKV?OpenDocument, accessed 8 February 2009.

[112] Wulf, W. (1998) 'The Urgency of Engineering Education Reform', *The Bridge - Frontiers of Engineering*, vol 28, no 1, www.nae.edu/nae/bridgecom.nsf/weblinks/NAEW-4NHMKV?OpenDocument, accessed 9 April 2009.

[113] Barnett, R. and Coate, K. (2004) *Engaging the Curriculum in Higher Education*, Society for Research into Higher Education (SRHE) and Open University Press, Buckingham, UK.

[114] Carew, A. and Cooper, P. (2008) 'Engineering curriculum review: processes, frameworks and tools', Proceedings of the Annual Meeting of SEFI July, Aalborg, Denmark.

[115] King, R. (2008) 'Addressing the Supply and Quality of Engineering Graduates for the New Century', Report on Engineering Education in Australia for the Carrick Institute for Teaching and Learning in Higher Education.

[116] Holt, P. and Romagnoli, J. (2003) *Chemical Engineering Curriculum Renewal for the 21st Century: A Work in Progress*, University of Sydney, Showcase 2003, Sydney, Australia.

[117] Wormley, D. (2004) 'Challenges in Curriculum Renewal', *The International Journal of Engineering Education*, vol 20, no 3, p4.

[118] Walkington, J. (2002) 'Curriculum Change in Engineering', *European Journal of Engineering Education,* vol 27, no 2, pp133-148.

[119] Crawley, E., Malmqvist, J., Ostlund, S. and Brodeur, D. (2004) *Rethinking Engineering Education: The CDIO Approach*, Springer, US.

[120] Campbell, D., Dawes, L., Beck, H., Wallace, S., Boman, M. and Reidsema, C. (2009) 'Graduate Attribute Mappingn with the Extended CDIO Framework', proceedings of the 20th Annual Conference for the Australasian Association of Engineering Education, 6-9 December 2009.

[121] Campbell, D. (2009) 'Workshop: CDIO – Participant Handbook', 20th Annual Conference for the Australasian Association of Engineering Education, 6-9 December 2009.

[122] Heywood, J. (2005) *Engineering Education Research and Development in Curriculum and Instruction*, Institute of Electrical and Electronics Engineers (IEEE), p16.

[123] Lundqvist, U. and SvanströM, M. (2008) 'Inventory of content in basic courses in environment and sustainable development at Chalmers University of Technology in Sweden', *European Journal of Engineering Education*, vol 33, Issue 3, pp355-364.

[124] Fenner, R., Ainger, C., Cruickshank, H. and Guthrie, P. (2005) 'Embedding sustainable development at Cambridge University Engineering Department', *International Journal of Sustainability in Higher Education*, vol 6, Issue 3, pp229-241.

[125] Olorunfemi, A. and Dahunsi, B. (2004) 'Towards a Sustainable Engineering Education and Practice in Nigeria', proceedings of the SEFI 2004 Annual Congress, *The Golden Opportunity for Engineering Education*.

[126] Onuki, M. and Mino, T. (2009) 'Sustainability education and a new master's degree, the master of sustainability science: the Graduate Program in Sustainability Science (GPSS) at the University of Tokyo', *Journal of Sustainability Science*, vol 4, no 1, pp55-59.

[127] Carew, A. and Therese, S. (2007) 'EMAP: Outcomes from Regional Forums on Graduate Attributes in Engineering', proceedings of the 2007 AaeE Conference, Melbourne.

[128] Allenby, B., Folsom Murphy, C., Allen, D. and Davidson, C. (2009) 'Sustainable engineering education in the United States', *Journal of Sustainability Science*, vol 4, no 1, pp7-15.

[129] HEFC (2007) 'HEFC Strategic Review of sustainable Development in Higher Education in England', Report to the Higher Education Funding Council for England by the Policy studies Institute, PA Consulting Group and the Centre for Research in Education and the Environment.

[130] RAE (2005) *Engineering for Sustainable Development: Guiding Principles*, Royal Academy of Engineering, UK.

[131] Spinks, N., Silburn., N. and Birchall, D. (2006) 'Educating Engineers for the 21st Century: The Industry View', Report by the Henley Management College for the Royal Academy of Engineering, March 2006.

[132] RAE (undated) 'Visiting Professor Scheme', www.raeng.org.uk/education/vps/sustdev/default.htm, accessed 27 August 2008.

[133] Leckstrom, J. (2008) 'Press Release: Kaplan Releases New College Guide 2009 Featuring 25 Green Colleges and 10 Hot Green...', *PRNewswire*, Tuesday 5 August 2008, www.reuters.com/article/pressRelease/idUS135812+05-Aug-2008+PRN20080805, accessed 30 October 2008.

[134] NewsWire (2008) 'Mater to Direct OSU Engineering Sustainability Programs', 30 October 2008, http://media-newswire.com/release_1077459.html, accessed 30 October 2008.

[135] Desha, C., Hargroves, K., Smith, M., Stasinopoulos, P., Stephens, R. and Hargroves S. (2007) *Energy Transformed: Australian University Survey Summary of Questionnaire Results*. The Natural Edge Project (TNEP), Australia.

[136] Desha, C. and Hargroves, K. (2009) 'Surveying the State of Higher Education in Energy Efficiency in Australian Engineering Curriculum', *Journal of Cleaner Production*, Elsevier.

[137] Jacobs, H. (1997) *Mapping the big picture: Integrating curriculum and assessment K-12*, Association for Supervision and Curriculum Development, Alexandria, Virginia.

[138] Hale, J. (2008) *A guide to curriculum mapping: Planning, implementing, and sustaining the process*, Corwin Press, Thousand Oaks.

[139] Crawley, E., Malmqvist, J., Ostlund, S. and Brodeur, D. (2004) *Rethinking Engineering Education: The CDIO Approach*, Springer, US.

[140] Biggs, J. and Collis, K. (1982) *Evaluating the Quality of Learning: the SOLO Taxonomy,* Academic Press, New York.

[141] Jolly, L. (2001) 'Graduate Attributes Factsheet: Implementing Graduate Attributes', The University of Queensland, http://www.vacs.uq.edu.au/final/1_10.pdf, accessed 12 November 2009.

[142] ABET (2008) *Accreditation Policy and Procedure Manual: Effective for Evaluations during the 2008-2009 Accreditation Cycle*, ABET, www.abet.org/forms.shtml, accessed 6 August 2008.

[143] Svanstrom, M., Lozano-García, F. and Rowe, D. (2008) 'Learning Outcomes for Sustainable Development in Higher Education', *International Journal of Sustainability in Higher Education*, vol 9, Issue 3, pp339-351, Emerald Press.

[144] Institution of Engineers Australia (2006) *Engineers Australia Accreditation Management System*, Institution of Engineers Australia System, www.engineersaustralia.org.au/education/program-accreditation/, accessed 31 July 2008.

[145] Bowden, J., Hart, G., King, B., Trigwell, K. and Watts, O. (2000) 'Generic Capabilities of the ATN University Graduates', a report from the Australian Technology Network, ('The ATN Project'), www.clt.uts.edu.au/ATN.grad.cap.project.index.html, accessed 16 June 2009, p2.

[146] Popp, A. and Levy, D. (2009) 'A Comparison and Evaluation of the CDIO Reference Syllabus against the Engineers Australia Competency Standards and the Development of a New Compact Framework', proceedings of the 20th Australasian Association of Engineering Education conference, 6-9 December, Adelaide, pp581-586.

[147] Carew, A. and Therese, S. (2007) 'EMAP Outcomes from Regional Forums on Graduate Attributes in Engineering', proceedings of the 2007 Australasian Association for Engineering Education (AaeE) Conference, Melbourne, December 2007, www.cs.mu.oz.au/aaee2007/papers/paper_31.pdf, accessed 6 August 2008.

[148] Svanstrom, M., Lozano-García, F. and Rowe, D. (2008) 'Learning Outcomes for Sustainable Development in Higher Education', *International Journal of Sustainability in Higher Education*, vol 9, Issue 3, pp339-351, Emerald Press.

[149] Campbell, D., Beck, H., Buisson, D. and Hargreaves, D. (2009) 'Graduate Attribute Mapping with the Extended CDIO Framework', proceedings of the 20th Australasian Association of Engineering Education Conference, 6-9 December 2009, pp598-604.

[150] Zou, P. (2008) 'Working Together to Achieve Graduate Attributes of Our Students', *Centre for Education in the Built Environment (CEBE) Transactions*, vol 5, Issue 1, pp25-42, The Higher Education Academy.

[151] EMAP (undated) 'Engineer Meta-Attributes Project', www.uow.edu.au/cedir/programs/emap/index.html, accessed 31 July 2008.

[152] Goldsmith, R., Reidsema, C., Campbell, D., Hadgraft, R. and Levy D. (2009) 'Designing the Future', proceedings of the 20th Australasian Association of Engineering Education conference, 6-9 December, Adelaide, pp293-298.

[153] Davis, R. and Savage, S. (2009) 'Built Environment and Design in Australia: Challenges and Opportunities for Professional Education', proceedings of the 20th Australasian Association of Engineering Education conference, 6-9 December, Adelaide, p800.

[154] Murdoch University (2004) 'Mapping the Graduate Attributes', Murdoch University Teaching and Learning Centre website, www.tlc.murdoch.edu.au/gradatt/mapping.html, accessed 29 October 2008.

[155] Lowe, K. and Marshall, L. (2004) 'Plotting renewal: Pushing curriculum boundaries using a web based graduate attribute mapping tool', in Atkinson, R., McBeath, C., Jonas-Dwyer, D. and Phillips, R. (eds) 'Beyond the comfort zone', proceedings of the 21st ASCILITE Conference, Perth, 5-8 December, pp548-557, www.ascilite.org.au/conferences/perth04/procs/lowe-k.html, accessed 29 October 2008.

[156] Swinburne University (2007) 'Curriculum Framework Project', www.swinburne.edu.au/hed/framework/statement.html, accessed 30 June 2008.

[157] Lamborn, J. (2008) Personal communications with J Lamborn, Senior Lecturer of Civil Engineering, Swinburne University, Melbourne, 14-30 August 2008.

[158] For example: Boks, C. and Diehl, J. (2006), 'Integration of sustainability in regular courses: experiences in industrial design engineering', *Journal of Cleaner Production*, vol 14, Issue 9-11, pp932-939.

[159] Lourdel, N., Gondran, N., Laforest, V. and Brodhag, C. (2005) 'Introduction of sustainable development in engineers' curricula - Problematic and evaluation methods', *International Journal of Sustainability in Higher Education*, vol 6, Issue 3, pp254-264, Emerald Press.

[160] Peet, D., Mulder, K. and Bijma A. (2004) 'Integrating sustainable development into engineering courses at the Delft University of Technology: The individual interaction

method', *International Journal of Sustainability in Higher Education,* vol 5, Issue 3, pp278-288, Emerald Press

[161] Lozano, R. (2006) 'A Tool for a Graphical Assessment of Sustainability in Universities (GASU)', *Journal of Cleaner Production*, vol 14, no 9-11, pp963-972.

[162] Roorda, N. (2001) *AISHE: Auditing Instrument for Sustainable Higher Education,* Dutch Committee for Sustainable Higher Education, www.dho.nl/documents/AISHE-Book1.5.pdf, accessed 30 August 2008.

[163] Cardiff University (2008) 'Helping Schools Assess their Sustainability', *Cardiff News*, February 2008, vol 15, no 5, p4.

[164] Lozano, R. (2008) 'Audit of Contributions of Cardiff University Curricula to Sustainable Development', *International Advanced Research Workshop on Higher Education for Sustainable Development*, Slovenia.

[165] Jezierski, G. (2008) 'Education for Sustainable Development in Wales', www.heacademy.ac.uk/assets/York/documents/ourwork/tla/sustainability/walesJune2008.pdf accessed 1 October 2008.

[166] Koth, B., Woodward, M. and Iversen Y. (2009) 'Civil Engineering Education for Sustainability: Faculty Perceptions and Result of an Australian Course Audit', proceedings of the 20th Australasian Association of Engineering Education Conference, 6-9 December, Adelaide, pp776-782.

[167] Hambur, S., Rowe, K. and Tu Luc, L. (2002) *Graduate Skills Assessment – Stage One Validity Study*, Evaluations and Investigations Program, Department of Education, Employment and Workplace Relations, March 2002.

[168] Lourdel, N., Gondran, N., Laforest, V. and Brodhag, C. (2005) 'Introduction of sustainable development in engineers' curricula - Problematic and evaluation methods', *International Journal of Sustainability in Higher Education*, vol 6, Issue 3, pp254-264, Emerald Press.

[169] Lourdel, N., Gondran, N., Laforest, V., Debray, B. and Brodhag, C. (2007) 'Sustainable development cognitive map: a new method of evaluating student understanding', *International Journal of Sustainability in Higher Education*, vol 8, Issue 2, 2007, pp170-182, Emerald Press.

[170] Desha, C., Hargroves, K., Smith, M., Stasinopoulos, P., Stephens, R. and Hargroves S. (2007) *Energy Transformed: Australian University Survey Summary of Questionnaire Results*. The Natural Edge Project (TNEP), Australia; Desha, C. and Hargroves, K. (2009) 'Surveying the State of Higher Education in Energy Efficiency in Australian Engineering Curriculum', *Journal of Cleaner Production*, Elsevier.

[171] Kronholz, J. (2008) 'US Universities Face Turbulent Times Ahead', *The Wall Street Journal* (Career Journal Section), www.imdiversity.com/villages/Careers/articles/collegejournal_highered_outlook_0305.asp, accessed 15 September 2008.

[172] Atkinson, C. (2008) 'Niche programs branch out into the unexpected', *Canadian Globe and Mail*, 14 February 2008, www.theglobeandmail.com/servlet/story/RTGAM.20080214.edu-specialtydegrees-0214/BNStory/education/home, accessed 12 August 2008.

[173] Koth, B., Woodward, M. and Iversen Y. (2009) 'Civil Engineering Education for Sustainability: Faculty Perceptions and Result of an Australian Course Audit', proceedings of the 20th Australasian Association of Engineering Education Conference, 6-9 December, Adelaide, p781.

[174] Ferrer-Balas, D., Adachi, J., Banas, A., Davidson, C., Hoshikoshi, A., Mishra, A., Motodoa, Y., Onga, M. and Ostwald, M. (2008) 'An international comparative analysis of sustainability transformation across seven universities', *International Journal of Sustainability in Higher Education*, vol 9, Issue 3, Emerald Press.

[175] Holmberg, J., Svanström, M., Peet, D., Mulder, K., Ferrer-Balas, D. and Segalàs, J. (2008) 'Embedding Sustainability in Higher Education through Interaction with Lecturers: Case studies from three European Technical Universities', *European Journal of Engineering Education*, vol 33, no 3, pp271-282.

[176] Holmberg, J., Svanström, M., Peet, D., Mulder, K., Ferrer-Balas, D. and Segalàs, J. (2008) 'Embedding Sustainability in Higher Education through Interaction with Lecturers: Case studies from three European Technical Universities', *European Journal of Engineering Education*, vol 33, no 3, pp271-282.

[177] Hadgraft, R., Xie, M, and Angeles, N. (2004) 'Civil and Infrastructure Engineering for Sustainability', Presentation to the 2004 American Society for Engineering Education Annual Conference, Salt Lake City.

[178] Hadgraft, R. (2008) Personal communications with Roger Hadgraft, Director of Learning and Teaching, School of Engineering, University of Melbourne, 16 September 2008.

[179] Stasinopoulos, P., Smith, M., Hargroves, K. and Desha, C. (2008) *Whole System Design - An Integrated Approach to Sustainable Engineering*, Earthscan, London, and The Natural Edge Project, Australia.

[180] Betts, M. (2009) Personal communication with Professor Martin Betts, Dean, Faculty of Built Environment and Engineering, Queensland University of Technology, 18 August 2008.

[181] King, R. (2008) *Addressing the Supply and Quality of Engineering Graduates for the New Century*, The Carrick Institute for Learning and Teaching in Higher Education Ltd, Sydney, p87.

[182] Massachusetts Institute of Technology (2008) 'Open Courseware', http://ocw.mit.edu/OcwWeb/web/courses/courses/index.htm, accessed 18 July 2008.

[183] United Nations Environment Program (2007) 'Sustainability Communications: A Toolkit for Marketing and Advertising Courses', http://opentraining.unesco-ci.org/cgi-bin/page.cgi?g=Detailed%2F1235.html;d=1, accessed 3 March 2010.

[184] United Nations Environment Program (2008) Resource Kit on Sustainable Consumption and Production, http://www.unep.fr/scp/publications/details.asp?id=WEB/0008/PA, accessed 3 March 2010.

[185] Laughborough University and the Higher Education Academy Engineering Subject Centre (2004) 'Toolbox for Sustainable Design Education', Department of Design & Technology at Loughborough University, Sponsored by The Higher Education Academy, Engineering Subject Centre, www.lboro.ac.uk/research/susdesign/LTSN/introduction/Introduction.htm, accessed 3 July 2008.

[186] Second Nature (undated) 'homepage', www.secondnature.org, accessed 31 July 2008.

[187] The Natural Edge Project (undated) 'Curriculum and Course Notes', www.naturaledgeproject.net, accessed 3 March 2010.

[188] RAE (undated) 'Visiting Professor Scheme for Sustainable Development – Case Studies', http://www7.caret.cam.ac.uk/case_studies.htm, accessed 3 July 2008.

[189] Brown, L. (2007) *Plan B 3.0: Mobilising to Save Civilisation*, W.W Norton & Company, New York.

[190] Hawken, P., Lovins, A. and Lovins, L. (1999) *Natural Capitalism: Creating the Next Industrial Revolution*, Earthscan, London.

[191] Stasinopoulos, P., Smith, M., Hargroves, K. and Desha, C. (2008) *Whole System Design: An Integrated Approach to Sustainable Engineering*, Earthscan, London, and The Natural Edge Project, Australia.

[192] Fien, J., Heck, D. and Ferreira, J. (eds) (1997) Learning for a Sustainable Environment: Professional Development for Teacher Educators, UNESCO-ACEID, Bangkok.

[193] Fien, J. and Tilbury (1996) Learning for a Sustainable Environment: An Agenda for Teacher Education in Asia and the Pacific, UNESCO-ACEID, UNESCO-ACEID, Bangkok.

[194] McKeown, R. (2002) Education for Sustainable Development Toolkit, Version 2.0, http://www.esdtoolkit.org/, accessed 3 March 2010.

[195] Desha, C., Hargroves, K., Smith, M., Stasinopoulos, P., Stephens, R. and Hargroves S. (2007) *Energy Transformed: Australian University Survey Summary of Questionnaire Results*. The Natural Edge Project (TNEP), Australia; Desha, C. and Hargroves, K. (2009) 'Surveying the State of Higher Education in Energy Efficiency in Australian Engineering Curriculum', *Journal of Cleaner Production*, Elsevier.

[196] Desha, C., Hargroves, K. and Reeve, A. (2009) *An Investigation into the Options for Increasing the Extent of Energy Efficiency Knowledge and Skills in Engineering Education*, Report to the National Model for Energy Efficiency, The Natural Edge Project (TNEP), Australia; Desha, C. and Hargroves, K. (2009) 'Surveying the State of Higher Education in Energy Efficiency in Australian Engineering Curriculum', *Journal of Cleaner Production*, Elsevier.

[197] McKenzie-Mohr, D. (2007) Fostering Sustainable Behaviour: An Introduction to Community-Based Social Marketing, 3rd Ed, New Society Press, Gabriola Island, BC.

[198] Desha, C., Hargroves, K. and Reeve, A. (2009) *An Investigation into the Options for Increasing the Extent of Energy Efficiency Knowledge and Skills in Engineering Education*, Report to the National Model for Energy Efficiency, The Natural Edge Project (TNEP), Australia.

[199] Smith, M.K. (1996; 1999) 'Andragogy', *The Encyclopaedia of Informal Education*, www.infed.org/lifelonglearning/b-andra.htm, accessed 11 September 2008.

[200] Goricanec, J. and Hadgraft, R. (2006) "Sustainable Practice "in action"', proceedings of the 17th Annual Conference of the Australasian Association for Engineering Education, AUT Engineering, Auckland, NZ.

[201] Chu, C. (2008) Personal communications with Professor Cordia Chu, Director, International Centre for Development, Environment and Population Health, Griffith School of Environment, Griffith University, 15 August 2008.

[202] Queensland Education and Training International (2008) '08 QETI Awards Booklet', www.studyqueensland.qld.edu.au/flyer_jpgs_pdfs/brochure_downloads/English/QETI%20Awards%202008%20low%20res.pdf, accessed 3 October 2008.

[203] Tongji University (2008) *Training Program Brochure*, Tongji University.

[204] Tongji University (undated) 'College of Architecture and Urban Planning', www.tongji-caup.org/en/index.asp, accessed 1 September 2008.

[205] Zhiqiang, W. (2008) 'Preface', *Training Program Brochure*, Tongji University.

[206] Powell, M. (2008) Personal communications with Professor Michael Powell, Pro Vice Chancellor (Business) Executive, Office of the PVC (Business), Griffith University, 27 August 2008.

[207] Custer, R. and Daugherty, J. (2009) 'Professional Development for Teachers of Engineering: Research and Related Activities', *The Bridge*, vol 39, no 3, www.nae.edu/Publications/TheBridge/16145/16204.aspx, accessed 21 December 2009.

[208] UNESCO (2001) 'Teaching and Learning for a Sustainable Future: UNESCO Multimedia Teacher Education Programme', www.unesco.org/education/tlsf/, accessed 18 July 2008.

[209] For further information, see www.zerilearning.org/, accessed 12 September 2008.

[210] For further information, see www.teachsustainability.com.au/, accessed 3 August 2008.

[211] The development of the 'Sustainability Education for High Schools: Year 10-12 Subject Supplements' has been supported by a grant from the Port of Brisbane Corporation and developed in partnership with Griffith University and the University of New South Wales as part of the Sustainable Living Challenge. Further information is available at www.naturaledgeproject.net/TNEPHighSchoolEducation.aspx, accessed 31 July 2008.

[212] Grant, M. (2008) Personal communications with Michelle Grant, Director of the YES Program at the Centre for Sustainability, ETHSustainability, ETH Zurich, 20 August 2008. More information available at www.sustainability.ethz.ch/en/index.cfm, accessed 20 August 2008.

[213] Takashi, M. (2008) Personal communications with Professor Mino Takashi, Director IR3S Program, University of Tokyo, 6 September 2008. Information about the Masters Program of Sustainability Science is available at www.sustainability.k.u-tokyo.ac.jp/, accessed 31 July 2008.

[214] ETHZurich (2008) 'YES Program', www.sustainability.ethz.ch/en/activities/braunwald.cfm, accessed 17 September 2008.

[215] IUTC (2008) 'Homepage', www.iutc.org/, accessed 31 July 2008.

[216] Forum for the Future (2008) 'Masters in Leadership for Sustainable Development: Prospectus 2009 – 2010', *Training Leaders for a Sustainable Future*, Forum for the Future: Action for a Sustainable World.

[217] Information about the Masters of Integrated Water Management is available at www.watercentre.org/education/masters, accessed 31 July 2008.

[218] For further information, see www.systemsdesign.polito.it, accessed 17 September 2008.

[219] Information on training programs offered by LEAD is available at www.lead.org/training/, accessed 18 September 2008.

[220] Wallace, K. (ed) (2005) *Educating Engineers in Design – Lessons Learnt from the Visiting Professors Scheme,* The Royal Academy of Engineering, p4.

[221] Allan, M. (2009) 'The Formation of the Engineer for the 21st Century – A Global Perspective', proceedings of the 20th Australasian Association of Engineering Education conference, 6-9 December 2009, pp447-452.

[222] King, R. (2008) 'Addressing the Supply and Quality of Engineering Graduates for the New Century', Report to the Carrick Institute (now the Australian Association for Teaching and Learning), March 2008, p106.

[223] Gilliot, D., Overlaet, B. and Verdin, P. (2002) 'Managing academic personnel flow at universities', *Tertiary Education and Management,* vol 8, pp277-295.

[224] Koth, B., Woodward, M. and Iversen Y. (2009) 'Civil Engineering Education for Sustainability: Faculty Perceptions and Result of an Australian Course Audit', proceedings of the 20th Australasian Association of Engineering Education Conference, 6-9 December, Adelaide, pp777.

[225] Lozano, R. (2006) 'Incorporation and institutionalization of SD into universities: breaking through barriers to change', *International Journal of Cleaner Production*, Issue 14, pp787-796.

[226] Wallace, K. (Ed) (2005) *Educating Engineers in Design – Lessons Learnt from the Visiting Professors Scheme,* The Royal Academy of Engineering, p4.

[227] Thomas, I. (2006) 'Sustainability and Universities', in Farrell, R. (ed), *Education for Sustainability, Encyclopedia of Life Support Systems (EOLSS)*, Developed under the Auspices of the UNESCO, EOLSS Publishers, Oxford ,UK, www.eolss.net, accessed 28 February 2007.

[228] Roberts, C. and Roberts, J. (eds) (2007) *Greener by Degrees: Exploring Sustainability through Higher Education Curriculum*, Geography Discipline Network, Gloucestershire, Chapter C5: Learning, Living and leading Green? Curriculum Policy for Sustainability, p321, www.glos.ac.uk/ceal/resources/greenerbydegrees/index.cfm, accessed 3 July 2008.

[229] Koester, R., Eflin, J. and Vann, J. (2006) 'Greening of the campus: a whole-systems approach', *International Journal of Cleaner Production*, Issue 14, pp769-779.

[230] Koth, B., Woodward, M. and Iversen Y. (2009) 'Civil Engineering Education for Sustainability: Faculty Perceptions and Result of an Australian Course Audit', proceedings of the 20th Australasian Association of Engineering Education Conference, 6-9 December, Adelaide, pp776.

[231] Tilbury, D. and Cooke, K. (2005) *A National Review of Environmental Education and its Contribution to Sustainability in Australia: Further and Higher Education*, Australian Government Department of Environment and Heritage and Australian Research Institute in Education for Sustainability, Canberra.

[232] Sharp, L. (2009) 'Greening your organisation', presentation at the Toohey Forest EcoCentre, hosted by the Australian Campuses Towards Sustainability, 19 October 2009.

[233] Thomas, I. (2006) 'Sustainability and Universities', in Farrell, R. (ed), *Education for Sustainability, Encyclopedia of Life Support Systems (EOLSS)*, Developed under the Auspices of the UNESCO, EOLSS Publishers, Oxford ,UK, www.eolss.net, accessed 28 February 2007.

[234] Thomas, I. (2006) 'Sustainability and Universities', in Farrell, R. (ed), *Education for Sustainability, Encyclopedia of Life Support Systems (EOLSS)*, Developed under the

Auspices of the UNESCO, EOLSS Publishers, Oxford ,UK, www.eolss.net, accessed 28 February 2007.

[235] Kift, S. (2008) '21st Century Climate for Change: Curriculum Design for Quality Learning Engagement in Law', *Legal Education Review*, vol 18, no 1 & 2, Australia, p1.

[236] McInnis, C. and Marginson, S. (1994) *Australian Law Schools after the 1987 Pearce Report,* Department of Employment, Education and Training, AGPS, Canberra.

[237] Weisbrot, D. (2001) 'What lawyers need to know, what lawyers need to be able to do: An Australian Experience', Erasing Lines: Integrating the law School Curriculum Conference, 26-28 July 2001, University of Minnesota Law School, Minneapolis, citing Australian Law Reform Commission (2000) *Managing Justice – A Review of the Federal Civil Justice System*, ALRC 89, 2000 ('ALRC Report No 89').

[238] Nelson, B. (2002) *Higher Education at the Crossroads – An Overview Paper*, Department of Education, Science and Training (DEST), Canberra, April 2002, www.dest.gov.au/crossroads, accessed February 2003.

[239] Sullivan, W., Colby, A., Wegner, J., Bond, L. and Shulman, L. (2007) *Educating Lawyers: Preparation of the Profession of Law,* the Carnegie Foundation for the Advancement of Teaching, Jossey-Bass, San Francisco.

[240] Kift, S. (2003) 'A Tale of two sectors: Dynamic Curriculum Change for a Dynamically Changing Profession', proceedings of the 13th Commonwealth Law Conference, 13-17 April, Melbourne Australia, p1.

[241] Kift, S. (2008) '21st Century Climate for Change: Curriculum Design for Quality Learning Engagement in Law', *Legal Education Review*, vol 18, no 1 & 2, Australia, p1.

[242] Kift, S. (2003) 'A Tale of two sectors: Dynamic Curriculum Change for a Dynamically Changing Profession', proceedings of the 13th Commonwealth Law Conference, 13-17 April, Melbourne Australia, p1.

[243] Kift, S. (2008) '21st Century Climate for Change: Curriculum Design for Quality Learning Engagement in Law', *Legal Education Review*, vol 18, no 1 & 2, Australia, p16.

[244] Kift, S. (2003) 'A Tale of two sectors: Dynamic Curriculum Change for a Dynamically Changing Profession', proceedings of the 13th Commonwealth Law Conference, 13-17 April, Melbourne Australia, p7.

[245] Vinten, G. (2000) 'The Business School in the new Millennium', *International Journal of Educational Management,* Emerald Press, vol 14, no 4, pp180-182.

[246] Paton, R., and Bevan, E. (2003) 'Changing Business Education, A profiling tool to assist strategic review in departments, programmes and management schools', *Learning and Teaching Support Network (LTSN), Business Education Support Team (BEST),* United Kingdom, p8.

[247] Matten, D. and Moon, J. (2004) 'Corporate Social Responsibility Education in Europe', *Journal of Business Ethics*, vol 54, pp323–337.

[248] United Nations (2007) *Principles for Responsible Management Education (PRME)*, published at the 2007 UN Global Compact Leaders Summit, Geneva, Switzerland, www.unprme.org/the-6-principles/index.php, accessed 3 August 2008.

[249] The Aspen Institute (undated) 'Beyond Grey Pinstripes', www.beyondgreypinstripes.org/index.cfm, accessed 16 June 2009.

[250] Park, H. (1998) 'Can business ethics be taught? A new model of business ethics education', *Journal of Business Ethics*, vol 17, no 9-10, pp965-77, cited in Vinten, G. (2000) 'The Business School in the new Millenium' *International Journal of Educational Management,* Emerald Press, vol 14, no 4, pp180-182.

[251] Paton, R. and Bevan, E. (2003) 'Changing Business Education, A profiling tool to assist strategic review in departments, programmes and management schools', *Learning and Teaching Support Network (LTSN), Business Education Support Team (BEST),* United Kingdom, p8.

[252] Matten, D. and Moon, J. (2004) 'Corporate Social Responsibility Education in Europe', *Journal of Business Ethics*, vol 54, pp323–337.

[253] Roper, J., Collins, E. and Pratt, M. (2003) 'Changing focus: A business school for sustainable development', in McIntosh, M., Shah, R. and Murphy, D. (eds) *Something to Believe in: Creating Trust*, Greenleaf Publishing, Sheffield.

[254] Roper, J. (2008) Written communications provided by Professor Juliet Roper, Associate Dean, Sustainability, University of Waikato Management School, 12 August 2008.

[255] Roper, J. (2008) Written communications provided by Professor Juliet Roper, Associate Dean, Sustainability, University of Waikato Management School, 12 August 2008.

[256] Roper, J. (2008) Written communications provided by Professor Juliet Roper, Associate Dean, Sustainability, University of Waikato Management School, 12 August 2008.

[257] Higgs, J. and Edwards, H. (1999) *Educating Beginning Practitioners,* Butterworth-Heinemann, London*,* p4.

[258] Allan, P. (1987) 'The Evolving Curriculum in Nursing Education', in Allan, P. and Jolley, M. (eds) *The Curriculum in Nursing Education*, Routledge, p209.

[259] Perry, E. (1987) 'Foreword' in Allan, P. and Jolley, M. (eds) *The Curriculum in Nursing Education*, Routledge, pix.

[260] Chaboyer, W., Willman, A., Johnson, P. and Stockhausen, L. (2004) 'Embedding evidence-based practice in a nursing curriculum: a benchmarking project', *Nurse Education in Practice,* vol 4, Issue 3, pp216-223.

[261] Krainovich-Miller, B. and Haber, J. (2005) 'Chapter 11: Transforming a Graduate Nursing Curriculum to Incorporate Evidence-Based Practice: The New York University Experience' in Levin, R. and Feldman, H. (eds) *Teaching evidence-based practice in nursing,* Springer Publishing Company, pp165-192.

[262] Singleton, J., Truglio-Londrigan, M. and Allan, J. (2005) 'Chapter 12: Incorporating Evidence-Based Practice into Clinical Education for Nurse Practitioners: The Pace University Experience', in Levin, R. and Feldman, H. (eds) *Teaching evidence-based practice in nursing,* Springer Publishing Company, pp193-204.

[263] Chaboyer, W., Willman, A., Johnson, P. and Stockhausen, L. (2004) 'Embedding evidence-based practice in a nursing curriculum: a benchmarking project', *Nurse Education in Practice,* vol 4, Issue 3, pp216-223.

[264] McAllister, M. (2001) 'Principles in practice: an Australian initiative in nursing curriculum development', *Nurse Education Today,* vol 21, pp315–322.

[265] Chaboyer, W., Willman, A., Johnson, P. and Stockhausen, L. (2004) 'Embedding evidence-based practice in a nursing curriculum: a benchmarking project', *Nurse Education in Practice*, vol 4, Issue 3, pp216-223.

[266] Ingersoll, G. (2000) 'Evidence-based nursing: what it is and what it isn't', *Nursing Outlook*, vol 48, pp151–152.

[267] Kessenich, C., Guyatt, G. and DiCenso, A. (1997) 'Teaching nursing students evidence-based nursing', *Nurse Educator,* vol 22, Issue 6, pp25–29.

[268] Levin, R., Feldman, H. (ed) (2005) *Teaching evidence-based practice in nursing,* Springer Publishing Company.

[269] Melnyk, B. (2005) 'Foreword', in Levin, R. and Feldman, H. (eds) *Teaching evidence-based practice in nursing,* Springer Publishing Company.

[270] Docking, S. (1987) 'Curriculum Innovation', in Allan, P., and Jolley, M. (eds) *The Curriculum in Nursing Education*, Routledge, pp149-163.

[271] Docking, S. (1987) 'Curriculum Innovation', in Allan, P., and Jolley, M. (eds) *The Curriculum in Nursing Education*, Routledge, p151.

[272] Chaboyer, W., Willman, A., Johnson, P. and Stockhausen, L. (2004) 'Embedding evidence-based practice in a nursing curriculum: a benchmarking project', *Nurse Education in Practice,* vol 4, Issue 3, pp216-223.

[273] Bellack, J., Graber, D., O'Neil, E., Musham, C. and Lancaster, C. (1999) 'Curriculum trends in nurse practitioner programs: current and ideal', *Journal of Professional Nursing,* vol 15, Issue 1, pp15–27.

[274] Giles, M. and Knight, L. (1996) 'Reengineering the traditional nursing curriculum', *JOCEPS: Journal of Chi Eta Phi Sorority,* vol 43, Issue 1, pp17–21.

[275] Knight, S. (1998) 'A study of the 'lived' experience of change during a period of curriculum and organizational reform in a department of nurse education', *Journal of Advanced Nursing,* vol 27, Issue 6, pp1287–1295.

[276] Thelin, J. (2000) 'A legacy of lethargy? Curricular change in historical perspective', *Peer Review,* vol 2, Issue 4, pp9–14.

[277] Ward, J., Gordon, J., Field, M. and Lehmann, H. (2001) 'Communication and information technology in medical education', *Lancet – Medical Education quartet*, vol 357, pp792-96, www.psychiatry.wustl.edu/Resources/LiteratureList/2001/May/Ward.pdf, accessed 15 June 2009.

[278] Ward, J., Gordon, J., Field, M. and Lehmann, H. (2001) 'Communication and information technology in medical education', *Lancet – Medical Education quartet*, vol 357, p795, www.psychiatry.wustl.edu/Resources/LiteratureList/2001/May/Ward.pdf, accessed 15 June 2009.

[279] ElAmin, A. (2008) 'Research driving ICT use in the Medical Sector', Innovations Report, 30 April 2008, www.innovations-report.com/html/reports/information_technology/report-109040.html, accessed 17 June 2009.

[280] Bach-Gansmo, E., Booth, A., Dørup, J., Fischer, MRG., Krarup, J., Medvedev, O., Nattestad, A., Petersson, G., Stensaas, S. and Winding, O. (2001) *Guidelines for using information and communication technology in medical education*, WFME Standing Committee, http://www2.sund.ku.dk/WFME/WFME%20News%20of%20Activities%20Report%20(kontorrapport)/WFME%20Guidelines%20Info%20and%20Communic%20Tech.htm, accessed 16 June 2009.

[281] Prideaux, D. (2007) 'Curriculum development in medical education: From acronyms to dynamism', *Teaching and Teacher Education,* vol 23, Issue 3 'Key Issues in Medical Education', pp294-302.

[282] Everingham, F. and Feletti, G. (1999) 'Chapter 10: Curriculum Management in a Changing World: The New Imperative', in Higgs, J. and Edwards, H. (eds) *Educating beginning practitioners: challenges for health professional education*, Elsevier Health Sciences, p79.

[283] Lehmann, H. (1998) 'Medical informatics, educational technology, and the new curriculum for the twenty-first century', Johns Hopkins University Press, Baltimore.

[284] Stanford University (2002) 'Dean's Newsletter', Stanford Medical School, December 2, 2002, http://deansnewsletter.stanford.edu/word_docs/DeanNews12-02-02.doc, accessed 16 June 2009.

[285] SUNY Downstate College of Medicine (undated) 'Report of the Sub-Committee on General Information and Opinions', SUNY Downstate College of Medicine – Curriculum Renewal Phase 1, www.downstate.edu/curriculum-renewal/pdf/Info-and-Opinions.pdf, accessed 16 June 2009.

[286] Taylor, I. (2009) 'Message from the Dean' SUNY Downstate Medical College of Medicine Curriculum Renewal, Brooklyn, New York, www.downstate.edu/curriculum-renewal/index.html, accessed 16 June 2009.

[287] Thomas, P. and Kern, D. (2004) 'Internet Resources for Curriculum Development in Medical Education - An Annotated Bibliography', *Journal of General Internal Medicine,* vol 19, pp599-605, www.som.tulane.edu/ome/helpful_hints/Internet_JGIM.pdf, accessed 16 June 2009.

[288] Thomas, P. and Kern, D. (2004) 'Internet Resources for Curriculum Development in Medical Education - An Annotated Bibliography', *Journal of General Internal Medicine,* vol 19, p599, www.som.tulane.edu/ome/helpful_hints/Internet_JGIM.pdf, accessed 16 June 2009.

[289] Heywood, J. (2005) *Engineering Education Research and Development in Curriculum and Instruction*, Institute of Electrical and Electronics Engineers (IEEE), p459.

4. REFLEXIVE INQUIRY INTO PROJECT EXPERIENCES

In this chapter, a process of reflexive inquiry into past experiences is used to further inform the investigation into curriculum renewal, using narrative perspective of a story-teller (i.e. using the personal pronoun 'I'). This chapter has been reviewed by a colleague for internal validity regarding timing and details, and to check for peer anonymity except where permission was obtained.

4.1 Introduction

I have selected an autobiographical, personal narrative approach to inform the investigation into curriculum renewal in urgent and challenging times, given the increasing acceptance of the use of personal experiences as a legitimate substantive data source within academic research (discussed in Chapter 2). As discussed in Chapter 3, researchers such as Barnett and Coate,[1] and MacDonald and Walker[2] suggest that large scale curriculum renewal processes begin with individual lecturers trialling new content and teaching methods within their own and colleagues' existing courses, as the opportunities and resources become available. Since 2004 I have been working as a lecturer and researcher, leading and participating in a number of curriculum renewal initiatives. While these were somewhat opportunistic (depending on funding availability and interested colleagues) and *ad hoc* in development and implementation (given the applied research approach), upon reflection, these experiences create a rich set of information.

An important component of reflexivity is exploring ways in which my involvement with a particular study might influence and inform my research.[3] Subsequently, I have used a strategic questioning profile to systematically inquire into each of my project experiences, asking: 1) What did the experience comprise?; 2) What did I learn from my experiences in this project, compared with the literature?; and 3) How could I apply learning from this experience to the elements of curriculum renewal emerging from the literature, and the process of rapid curriculum renewal? I have data (including journal notes, email correspondence, project reports and other deliverables) for a number of project experiences between 2004 and 2009, as shown in Table 4-1.

The data is discussed in two parts, beginning with my lecturing experiences and then following with research experiences regarding insights into how these relate to the literature findings, the timing and staging implications with regard to a process of rapid curriculum renewal. This clustering of discussions aims to ensure that any positional differences between my lecturer role and researcher role do not confuse discussions about the experiences.

Table 4-1. Summary of elements considered in the reflexive inquiry

Element	Summary description of personal experiences and roles
Awareness raising and developing a common understanding	Lecturer experiences: Faculty sustainability seminar (host); Faculty sustainability forum (host); Faculty course design workshop (organiser and participant). Researcher experiences: 2007 national survey of engineering educators (co-chief investigator); 2009 engineering education survey (co-chief investigator).
Graduate attribute mapping	Researcher experiences: School level graduate attribute mapping (co-chief investigator).
Curriculum auditing	Researcher experiences: Curriculum audit for sustainability content (co-chief investigator).
Content development and renewal	Lecturer experiences (course convenor): Developing new content for a first year course; Using an open-source 'drop-in' module in first and second year courses; Developing a new second year flagship course using open-source content; Evolving a first year flagship course using open-source content; Developing new content for a final year/ masters course; Running a short course intensive. Researcher experiences: Specialised text books including *Natural Advantage of Nations, Whole System Design, Energy Transformed, Factor Five, and Cents and Sustainability* (co-author); Introductory module content development (co-author); National pilot of introductory content; content development – undergraduate course; content development – postgraduate courses (co-chief investigator);
Bridging and outreach	Lecturer experiences (course convenor): Content development; Teacher awareness training. Researcher experiences: Website development (contributor); In-house training (co-facilitator); Inter-departmental strategic planning workshops (co-facilitator).
Campus Integration	Lecturer experiences (course convenor): Seeking projects for assessment items from other departments; submissions to senior management.

4.2 Reflexive inquiry into lecturer experiences

Through my lecturer role in the School of Engineering over the last five years I have attempted several curriculum renewal initiatives. Using the process highlighted in the previous section, personal perspectives and insights gained from the reflexive inquiry process are summarised in the following paragraphs.

4.2.1 Awareness raising and developing a common understanding

4.2.1.1 Faculty sustainability seminar

In 2004 a senior colleague and I successfully applied for a small internal university grant to organise a one-day Sustainability Forum in March 2005 for the Faculty of Environmental Sciences. The aims of the day were to raise awareness about the need to further integrate sustainability into engineering and science education, through providing an opportunity for staff discussion in an informal setting. Thirty-seven participants were present, of approximately 60 full time staff.

Experiences from the seminar also align with the literature findings that awareness raising is an important component of rapid curriculum renewal that should appear early in the process. According to the formal seminar evaluations the majority of participants desired to have more opportunities like this to discuss the future of the faculty and opportunities to interact better between schools. Given the lead time in organising this event, at least a six to twelve month timeframe would be required for this component, to allow the organisers to promote and hold such events.

Experiences from the seminar also correlate with the literature findings that senior-management support for events such as seminars and forums, is essential. For example, participants in the seminar initially expressed hesitancy in being involved, as such initiatives were not considered important during performance reviews. However, the internal financial support at a Group level within the University appeared to be very influential in encouraging colleagues to attend. However several staff expressed frustration during the day and in the post-seminar evaluation, that there was no commitment or seed funding from upper management to get started on such curriculum renewal. As one participant commented in their seminar evaluation, '[Curriculum renewal] *all starts with leadership and vision, with resources made available to support and we learn through them. We don't appear to be even close to this process'*.[4]

4.2.1.2 Faculty sustainability forum

In conjunction with applying for the sustainability seminar grant, in 2004 a senior colleague from Civil Engineering (EIT) and I obtained a second internal Signature

Grant to consider the introduction of similar material across all engineering disciplines, through two workshops on both campuses offering engineering. In June 2005 at the first of the workshops, a number of invited speakers shared their collective experiences and knowledge of the sustainability concept, its effect on modern engineering practice and its importance to the profession. This was followed by a session with Gold Coast campus staff where academics brainstormed various ways to incorporate sustainability into the curriculum. A key objective of this forum was to provide the opportunity for Griffith staff (representing different disciplines) to interact with each other and share challenges around sustainability education, experiences and opportunities.

My primary learning from this experience was that I had underestimated the effect of existing barriers to curriculum renewal within the system, related to programming and accreditation timelines. Hence, while I was hopeful that I could achieve such integration in perhaps 1-2 years for trialling and incorporation of content across and within the programs, the system was indeed working to a much longer timeframe of at least 5-10 years for program integration of sustainability content, as described in the literature. The experience also highlighted the minimum timeframe of about six months to organise and hold these events on both campuses.

4.2.1.3 Faculty course design workshop

Part of a common course initiative that began in 2006 included developing a new first year first semester course called ‘Engineering Practice and Sustainability’ in the engineering school, for which a working party was created. Given the moves for common course development, the second part of the signature grant was re-scoped to consider this course. This was believed to be particularly timely and worthwhile given that Engineers Australia, in their recent accreditation review, had recommended looking at how generic skills and sustainability critical literacies were embedded into the degree program (e.g. through a mapping exercise). Furthermore, the new common course (to be taught in Semester 1, 2007) would take the place of a number of different discipline-specific courses taught in the previous schools, and the new course needed to be taught across campuses.

Directed by an external facilitator, participants (including me) were asked to brainstorm for four domains (i.e. ‘Personal, Community, Environment, Economy’) a number of ‘indicators of success’ for graduates at a program level, with regard to ‘student attributes’ (Character), ‘student literacies’ (Knowledge), and ‘student competency’ (Ability). Participants then prioritised this list with regard to what they believed students should be exposed to in the common course. A system of ‘H’ (have to include), ‘M’ (may be taught) and ‘L’ (able to be left until later in the degree program) was used.

Following the workshop, the information was intended to be used to prepare a draft course outline, after which it would be checked against the attributes discussed in the workshop. However, this did not happen as planned, due to the desire in the following months by other staff within the school to just splice in lectures from the various component courses, with a 3-week module on sustainability.

From this experience I learned that within a workshop environment, a formal process of considering course content could be undertaken within a matter of hours, in an open, collaborative environment, if it is supported by upper management. Even with up to a month of organising prior to the event and up to a month of post-workshop comments and feedback on a drafted course outline, this process could be completed within two months. However, in hindsight it is clear that if the criteria for the course being planned is not clear, then the outcome may be affected (i.e. diluted or otherwise changed) by other demands from school and faculty over the following months and years.

4.2.2 Content development and renewal – undergraduate

4.2.2.1 Developing new content

In Semester 2 2004, I tried re-writing a standard materials course for first year environmental engineering students, to provide a new sustainable development perspective in 'Mechanics and Materials' (part of my employment requirement in replacing a previous staff member).[5] This included more interactive classes (informal student presentations), a group assignment which I intended to encourage students to think laterally about innovations in materials and their potential for use in society, and two guest lecturers (one internal, one external) on the theory of plastics and cement. I repeated my version of the course in 2005, then in 2006 and 2007 when the course was merged with a civil engineering equivalent and my component was reduced to a 3-week module on sustainable materials at the end of the semester. In 2008 as part of further program restructuring, I was no longer involved in the course, and the sustainability content that I had developed was no longer offered.

While the majority of student evaluations regarding the sustainability-related content were complementary over the years,[6] I experienced the time shortage issue documented in the literature, particularly in preparing content on topics with which I was not familiar, without having any existing modules or notes to rely on.[7] It was difficult to find lesson-friendly literature specifically on various material alternatives, and there were few good references to provide students with for their major assignment. I was tempted on a number of occasions to revert back to the older material, with

student interest providing the only major incentive to continue to explore innovative options.

While in the short term the course transitions seemed beneficial in enabling the integration of sustainability content beyond environmental engineering into a course also offered to civil engineering, the subsequent closure of the course curtailed longer-term progress. Despite my recollection of being enthusiastic about meeting new course needs, journal notes document my personal frustration at developing new content 'on the run' for a continually changing course that would run for only two more years (part of a program restructuring), making the investment of time and resources seem futile.

Upon reflection, I learned the importance of other staff being knowledgeable about the importance of, and how to embed sustainability content into, the curriculum, so that the inclusion is not dependent on the participation of just one staff member. I also realised that these experiences align well with the element related to strategic content development and renewal, where it is not sufficient just to have a lecturer who is enthusiastic about course renewal; for longevity course renewal must be strategically planned and embedded within larger program considerations at a departmental level. This highlights the need for this component to be focused on later in the curriculum renewal process, after activities such as awareness raising, attribute mapping and curriculum auditing, where the changes are planned and purposeful. Furthermore, the process of embedding new content may be quite drawn out over a number of years unless there are content and other staff resources provided to motivate and support the staff responsible for the actual curriculum renewal.

4.2.2.2 Using open-source modules

In Semester 2 2004, I trialled part of a sustainability module that I had previously helped develop (through my research role) on 'Introducing Sustainability', as a two-week module as part of a second year environmental engineering design course 'Design 1'.[8] In 2005, I tried using the same introductory 2-week 'drop-in' module for first year environmental engineering students, in 'Professional Practice and Skills 1'.[9]

My experience with this style of new content delivery aligned with suggestions in the literature that such 'drop-ins' can feel like add-ons and disconnected from the rest of the students' learning experiences. According to feedback from the second year students (anonymous evaluation forms completed at the end of the second week, 100 percent response rate), this 'drop in' module was very popular, but the connection to the rest of the course or their environmental engineering degree program was not evident.[10] Feedback from a similar evaluation survey of the first year students indicated that the material was well received (100 percent response rate), with one student

noting, *'Very interesting and informative. Congratulations - my most interesting lecture so far'*.[11] However, some respondents felt that the lecture went too fast through some material in both weeks, with another student writing, *'Great info, starting to understand the role of enviro engineers. Nice presentation style - conversational. Maybe too much info - good info though!"*[12]

This experience supports the literature finding that 'drop-in' modules are popular as a flexible tool to meet student needs across year levels where similar gaps in new knowledge and skills are present. However, while short modules on a topic may be beneficial in raising awareness among students about emerging concepts and issues, students may be disenfranchised if this experience is not in synergy with the remainder of their program experiences. Hence, these 'flagship' modules need to be used carefully in the program, within a larger scaffold of aligned curriculum renewal actions.

4.2.2.3 Developing a new flagship course

The module that I trialled in 2004 and 2005 evolved over the following two years into a full second year environmental engineering course, titled 'Sustainability Principles and Practices', which relied on open-source course notes of the same name.[13] In 2006 I was provided with funding to co-ordinate a research assistant to create workshops and tutorials from the course notes, while I liaised with approximately 12 other lecturers and guest speakers to fill the lecture, tutorial and workshop sessions. In 2007 I reduced the number of teaching staff involved to streamline the convenorship, relying on one sessional lecturer to teach the subject areas I was not as familiar with. However, as a result of program restructuring and consolidation this course was then terminated. One of the modules from this course on 'Whole System Design' was subsequently expanded and used in 2008 and 2009, in 'Engineering Design Fundamentals', where this specific sub-topic of the original course was increased from 3 weeks to 6 weeks.

In 2006 in addition to standard university course evaluations, as the course convenor I evaluated the students' learning through the use of an increasingly popular mind map methodology,[14,15,16] in two class-based brainstorming sessions.[17] At the beginning and end of the module, 21 students completed a mind map on their appreciation of the topic, which highlighted areas that they were and weren't grasping. The informal evaluation of this survey data aligned with research by authors such as Lourdel,[18] Carew and Mitchell,[19] and Segalàs *et al*[20] who discuss the potential for demonstrating improvement in conceptual understanding.

The experience aligned with commentary in the literature that program management is highly dynamic, where unless the overall program design and management is systematically co-ordinated with a rigorous understanding of learning outcomes and

graduate attribute development (i.e. through formal evaluation and review), such innovative practices in sustainability curriculum renewal can be inadvertently removed from programs as part of larger restructuring and consolidation initiatives.

4.2.2.4 Evolving a flagship course

Further to the successful 2005 trial of the two week sustainability module in the first year course 'Professional Practice and Skills 1', this course was renamed 'Introduction to Engineering and Sustainability' in 2006, where I taught from a set of open-source notes 'Introduction to Sustainable Development'[21] for all 13 teaching weeks. I also ran a two day field trip where all students visited a local Island to see the types of issues that environmental engineers may encounter. In 2007 the course was merged with several other courses in other disciplines to create a 'common first year course' called 'Engineering Practice and Sustainability' which was offered on two campuses to approximately 160 students. As part of the consolidation, I taught the sustainability content on both campuses, which was reduced from 13 to 5 weeks for environmental engineering students, and increased from 0 to 3 weeks for all other disciplines (civil, micro-electronic, and software engineering students).

My journal notes record my comment that this transition was very similar to the outcome for the second year course discussed above.[22] More students had access to sustainability content, but the extent had been diluted from the original full-course focus. While feedback from the annual student cohort of approximately 35 students was very positive it was also clear from the students' evaluation, that they were disenfranchised with the lack of sustainability content elsewhere in their degree.[23] In this sense the flagship course was beset with similar challenges as the drop-in modules trialled previously, with regard to being seen as 'stand alone' considerations.

Each year in the three years that the course has been running in this format, the sustainability module consistently rates as the most interesting component of the course.[24] Anecdotally it seems that the field trip and sustainability component has also helped improve retention in the environmental engineering discipline,[25] although no formal survey of this factor has been studied. However, while the field trip was a very rewarding component of the curriculum and highly praised by students,[26] in reflecting about replicability, it is clear that this type of activity – which can be time consuming and which is management-heavy – is dependent on the individual lecturer being comfortable with the content, and with taking field trips of this type. Should it be clearly embedded within a larger strategic plan for the program, then funds could perhaps be made available to support staff in creating such 'flagship' learning opportunities.

4.2.3 Content development and renewal – postgraduate

4.2.3.1 Developing new content

In 2004 I was assigned the course 'Environmental Management Systems' which was offered to both undergraduate students in their final year, and masters students in flexible delivery mode, both on campus and off-campus. In the 6 years that I have convened the course, I have had many opportunities to alter the content and delivery as the numbers grew from around 50 students to more than 100 students. This included: making the assessment item an actual project within an organisation chosen by the students; introducing the sustainable development notion of moving 'beyond compliance' with associated new content; and involving industry and professional associations as keynote lecturers during the semester. In 2008, the school made the course a compulsory part of the environmental management masters program. In 2009 although it was changed back to an elective as part of program restructuring, the number of enrolled students remained constant.

Reflecting on my long-term experiences as a convenor for this course, I benefited from the certainty of course continuation, and the subsequent freedom to continually review and vary course content and student learning experiences without the imminent threat of course closure/ consolidation. In contrast to the first year experience, my journal notes from 2005-2006 reflect a long-term planning horizon of 5 years, systematically planning content renewal for various modules within the course, which I developed with some sessional support funding from the school. I have also been able to engage with internal teaching and learning support, to introduce blended learning opportunities such as lecture-capture and discussion boards alongside content renewal.

Considering this experience within the content development element of curriculum renewal, it seems that a stable curriculum environment with available school support for renewal can be important mechanisms in promoting regular review and updating of content in a systematic manner, helping to create an opportunity for an accelerated process.

4.2.3.2 Running a short course intensive

In 2005 I participated as a lecturer in a 'National Pollutant Inventory Short Course' run in collaboration with state government. Through this experience I learned the process of running an informal intensive short course in the university system. In 2006, I sought approval for two intensive short courses developed by The Natural Edge Project to be given unspecified credit at Griffith University. This was agreed, and in July and

September of 2006, a colleague and I ran two short course intensives on the 'Introduction to Sustainable Development' and 'Sustainability Principles and Practice'.

My journal notes and correspondence[27] reflect my surprise that this method of teaching was not more popular within the university system, given the potential to attract industry professionals to masters programs, and to generate funds for academics to pursue their research or teaching interests. Most of the students in each of the two classes were from industry, not yet enrolled in a masters program. Indeed, one state government agency sponsored 10 places in the course for employees. Verbal feedback and informal written evaluations by students show that a significant attraction for the short courses was the potential for it to contribute as a course on the students' formal academic transcript.

My key realisation from these experiences is that the logistics of organising such courses can be overwhelming to a staff member, for example in knowing how/ where payments should be made, how the credit for the course can be applied in the participating institutions, whether students can opt for a non-assessed 'participation' or assessed and graded 'attainment', and how the learning may be formally recognised by the various professional bodies as continued professional development. However, once the logistics are understood, there appears to be significant interest in the workplace for these types of academically rigorous learning opportunities, which aligns with the increasing demand noted in the literature.

4.2.4 Bridging and outreach

Alongside convenorship activities and research, in 2005 the Faculty of Environmental Sciences invited me to instigate and manage a program called, 'The Sustainable Living Challenge', which was developed by the University of New South Wales in the late 1990s in partnership with the United Nations Environment Program.[28] In 2007 I handed the management role to Mr Hargroves (TNEP) and remained part of the team providing outreach through content development and awareness raising as follows.

4.2.4.1 Content development

Through industry funding, I developed a number of education modules for high schools in collaboration with TNEP, with the aim of encouraging school leavers to enrol in engineering and science programs at university. In addition, through a separate grant from DELL, the TNEP research team developed content for high school students and undergraduate university students on emerging trends relating to E-Waste.

Reflecting on these content development initiatives, the projects were important experiences for me to learn how university content could be efficiently and effectively

translated for high school audiences, and also opportunity for selected university course offerings to senior year students, encouraging further study at university.

4.2.4.2 Teacher awareness raising

Between 2007 and 2009 I was involved in several teacher training events in collaboration with the EcoCentre and the SLC, where teachers were encouraged to join the challenge and use the educational materials developed. Reflecting on these and other interactions with high school teachers over the 4 years of involvement with the SLC, my experiences appear to align with those documented in the literature, which encourage such interactions to increase the student demand for sustainability content in university programs.

4.2.5 Campus integration

4.2.5.1 Seeking projects from other departments

Over the last five years there has been increasing interest at the group level and higher management levels in the university, with regard to opportunities in moving toward sustainable campus operations. A number of colleagues have enquired about whether my students (through the courses that I convene), would be interested in undertaking projects on campus to assist the university in considering topics such as electronic waste, energy efficiency and water consumption.[29]

It became clear over the years that this could be an opportunity to increase awareness on campus about sustainability issues, and to give students access to 'real projects' in their coursework. However, in attempting to do this in my Environmental Management Systems course, I have learned that there are a number of challenges to doing so, including: liability (i.e. regarding students giving advice); limited timeframe and scope for project work (i.e. within the teaching semester); quality variability (i.e. depending on the students' capabilities); and a lack of willingness to supervise or spend time assisting students working on such projects (i.e. providing data, answering questions).

4.2.5.2 Submissions to senior management

In the last three years, there have been a number of opportunities for me to provide feedback to senior management within the university regarding curriculum issues. These have related to the merits of a niche degree on sustainability versus integration of sustainability content within existing degrees, opportunities for integrating curriculum renewal with greening campus operations, and the need to audit curriculum to fully understand where the opportunities exist. They have also included feedback on the need to map the desired attributes throughout the curriculum before defining

coursework and learning outcomes, and the merits of auditing and graduate attribute mapping, to ensure that the curriculum meets accreditation requirements with regard to embedded sustainability content, in the upcoming accreditation round.

Collectively considering these experiences, it became apparent that I have been using these opportunities to seek feedback for myself, on the elements of curriculum renewal that I have seen emerging in the literature. Each experience has helped me to clarify the elements and to further elaborate their implications in a format that was amenable to the various academic audiences.

4.3 Reflexive inquiry into experiences as a researcher

Through my interactions with several major academic institutions over the last 5 years, I have led and participated in a number of curriculum renewal activities. Using the process highlighted in Chapter 2, and in Section 4.1, these experiences are summarised below, together with my key learnings in relation to the literature.

4.3.1 Developing a common understanding

The following paragraphs describe two research projects which I led in my role within the TNEP team, funded by the National Framework for Energy Efficiency (NFEE), and my reflections on how these experiences contribute to my understanding of rapid curriculum renewal for EESD. Full results for the 2007 survey were published in a public report to the NFEE,[30] and a summary paper was published in the *Journal of Cleaner Production*.[31] Full results for the 2009 investigation were also published in a public report to the NFEE,[32] and a summary of results are intended for publication in an online textbook on energy efficiency and engineering education.

4.3.1.1 2007 engineering education survey

In considering the possibility of undertaking a national survey of engineering education on the topic of sustainable development, it became clear in discussions with NFEE staff that the sub-topic of energy efficiency could be a prime example for a new area of practice that needs to be rapidly integrated into engineering courses, while also addressing a knowledge gap in a topical content area. Furthermore, a project focused on energy efficiency could provide valuable parallels for a range of sustainable engineering related topics, such as water and materials efficiency. Hence, in 2007 the National Framework for Energy Efficiency (NFEE) funded TNEP to undertake the first survey of energy efficiency education across all Australian universities teaching engineering education, which I led, asking, '*What is the state of education for energy efficiency in Australian engineering education?*'.[33]

The subsequent research project used questionnaires for staff and students, the results of which were cross-checked for additional context and validity of interpretation through semi-structured telephone interviews with a subset of Australian academics who were experienced in engineering education for energy efficiency. Responses from 27 of the 32 universities teaching engineering education across Australia (including 48 courses taught by 44 lecturers) suggested that energy efficiency education is currently highly variable and *ad hoc* across universities and engineering disciplines. Moreover, there is an urgent need to embed energy efficiency knowledge and skills into engineering

curriculum, beyond once-off courses, special interest topics in later years, or highly specialised masters programs.

Reflecting on the survey findings, it is clear that it contributes to a growing global understanding of the current state of education in this sustainability topic, confirming that the reality for engineering schools in Australia aligns with the literature findings. These survey findings are also immediately relevant for senior management in engineering departments, Australian professional organisations, and government departments considering future programs and funding allocations, as they provide an indication of the preferred options for increasing energy efficiency education.

4.3.1.2 2009 engineering education survey

Following the insights gained through the 2007 survey, I learned that there were a number of significant barriers prevalent within the existing curriculum, which was subsequently explored in a second project funded by NFEE. This new initiative focused on developing a free and publically available strategic document to assist the curriculum renewal process for energy efficiency education, drawing upon behaviour change tools in a 'Community Based Social Marketing' (CBSM) methodology.[34]

The resultant research project in which I played a primary role, was undertaken to provide guidance to assist engineering educators considering curriculum renewal in the area of energy efficiency education. The findings of this research were intended for use by engineering departments, accreditation agencies, professional bodies and government, to identify opportunities for moving forward and then to strategically plan the transition. The project provided a significant opportunity to explore options to support lecturers, program co-ordinators and senior staff to strategically approach, in an informed way, the challenge of increasing the extent of energy efficiency education.

The project methodology involved a multi-stage process, including a literature review, a survey, and applying the relevant parts of the CBSM approach to education for energy efficiency within the engineering education community of practice. Ten curriculum renewal behaviours were short-listed and these were subsequently investigated for drivers that both limit and promote rapid curriculum renewal. The most common barriers included: lack of available data/ information; lack of knowledge; lack of time for preparation; an overcrowded curriculum; and prohibitive cost. The most common benefits included: improved marketability; improved pedagogy (problem based learning); and improved pedagogy (generic skills).

Through this project experience, I learned more about the drivers that might promote and limit rapid curriculum renewal at the level of implementation. The survey results

aligned well, and in many cases provided more detail about, the drivers highlighted in the literature review. Despite the lack of literature and scarcity of precedents on tools and strategies to encourage curriculum renewal through reducing such barriers and increasing such benefits, a number of strategic components were highlighted in the literature, which could be of use to engineering departments considering how to increase the extent of energy efficiency within their programs. In addition to opportunities at the level of the lecturer and engineering department, the research highlighted key roles for accreditation agencies, professional bodies and government, which could help to catalyse timely curriculum renewal. This included: the role for accreditation bodies to include energy efficiency within accreditation requirements; the role for professional bodies in providing content development and professional development support for educators; and the role of government in providing clear signals on the key role of energy efficiency in all major infrastructure and service provision across society, and to support capacity building initiatives put forward by engineering departments, accreditation agencies and professional bodies.

4.3.2 Graduate attribute mapping

In early 2010, Mr Hargroves and I were invited to collaborate with the engineering department at James Cook University on a 'curriculum refresh' project which had received funding from the federal government. The project was targeted at integrating sustainability into the curriculum through a rigorous methodology. Subsequently the project was undertaken in three phases including some initial awareness raising activities, a school-level graduate attribute mapping initiative, followed by some pilot content integration into identified high priority subjects. The graduate attribute mapping tasks included an initial workshop between the university project leaders and Mr Hargroves and myself, to develop a mapping template that fit within the university's reporting structure and culture. We then visited the campus and facilitated an onsite workshop over three hours, which 80 percent of the school staff attended on invitation. Once the workshops were completed, the workshop outcomes – lists of prioritised graduate attributes by discipline – were documented for input into subsequent curriculum refresh activities within the school (including an internal audit of subjects).

The curriculum auditing process highlighted two issues identified in the literature. Firstly awareness raising is a critical pre-requisite for graduate attribute mapping, to avoid tension within the school that is based on varied appreciation of what 'sustainability' is referring to. It also serves to increase staff buy-in to the process, which they are potentially being asked to contribute to in their own time. Secondly, upper management support is critical to ensuring that curriculum mapping is undertaken with purpose. In

particular, where there are opportunities to report on progress with graduate attribute mapping to senior university staff, this has the potential to feed into attribute development within the larger university context.

4.3.3 Curriculum audit for sustainability content

In late 2006, Mr Hargroves and I were invited to undertake an audit of the first year civil engineering undergraduate program at Monash University, to determine how well the program integrated sustainability language, content and application. Specifically, the engineering department was interested in addressing its risk exposure to changing graduate needs in Australia, from shifts in Australian and international legislation, and industry demand. We therefore focused on auditing against what we perceived and understood to be likely future graduate needs over the next decade based on our research and experience. Driving factors for the desktop audit included:[35] the need to satisfy Engineers Australia's competency requirements in the 2008 accreditation review; the need to meet changing student expectations on course content (i.e. recruitment); and the need to meet Industry's evolving needs for engineering graduate skills and competencies.

Market leader graduate attribute criteria were used to assess each course's performance profile according to the level of embedded sustainability content. A strengths and weaknesses analysis was used to asses each course, which included recommendations for where content could be obtained to improve the course curriculum. The results and recommendations for each course were provided to each of the relevant faculty member/s by the First Year Director for review as to the congruency of information and interpretations. It also provided an opportunity to discuss what the findings meant and what opportunities and constraints there were to moving forward with that particular course. The report was then finalised and the reports were submitted to management, for planning the curriculum renewal process. A paper which included a summary of the process was also subsequently published.[36]

The curriculum auditing process highlighted a number of issues identified in the literature. Firstly, it was very important from the commencement of the project that staff perceived the initiative as collaborative and non-confrontational. Secondly it was important to engage directly with the staff to talk about their courses, as many items relating to embedding new content was in their course, but not documented in their course outline or assessment items. Thirdly, staff were interested in how the audit could help demonstrate their sustainability content in the next accreditation review.

4.3.4 Content development and renewal - specialised text books

My experiences with TNEP began in 2002, when I became frustrated by unsustainable development pathways in industry, which were not adopting innovations highlighted in publications such as *Factor Four*[37], *Natural Capitalism*[38] and *Cradle to Cradle*[39] (which did not appear in my undergraduate training). Reading the work of such leaders transformed my growing anxieties about the future into a drive to contribute to changing it, through capacity building for sustainable development. Several experiences in such content development are summarised in the following paragraphs.

4.3.4.1 The Natural Advantage of Nations

The team's first project was a three-year process, working with many co-authors, mentors and advisors, to publish *The Natural Advantage of Nations*[40] in 2005 (of which I am a co-author), as a response to *Natural Capitalism*. Working on this book allowed our team to focus on catching up with the field of sustainable development, to study the work of the leaders, and to meet with them to discuss their ideas and experience.

I was continually surprised by the openness with which all of the experts we approached offered, such as meeting Amory Lovins at an event in Canberra that led to my two colleagues staying at Rocky Mountain Institute for three weeks, or sitting in the lounge of Jim McNeill and discussing the best way to respond to *Our Common Future.*[41] Experiences like this allowed us to take what we read and then explore it in conversation with its creators, piecing it together and beginning to see that a truly integrated approach was the only way to bring the reality of the dream that these leaders were creating to life.

Reflecting on the emerging elements of curriculum renewal, the importance of support for awareness raising among staff and students is highlighted in this experience. Through professional development I was able to begin to understand the opportunities for a new and emerging topic area, both in my research agenda, and the potential for educational application. Another significant learning from this experience was the importance of a peer network to encourage such professional development – in this case my research colleagues.

4.3.4.2 Whole System Design

In 2003, sustainable development expert Amory Lovins advised our team that we could contribute to the, *'non-violent overthrow of bad engineering'*.[42] This and subsequent conversations led to developing the 2009 publication, '*Whole System Design – an Integrated Approach to Sustainable Development',*[43] developed in partnership with UNESCO, the World Federation of Engineering Organisations, and the Australian

Government. Amory also impressed upon our team the importance of working with the engineering community to help share and mainstream insights from *Factor Four* and *Natural Capitalism.* This was made possible through support from the Institution of Engineers Australia and the World Federation of Engineering Organizations.

In writing this textbook, the three other co-authors and I decided to use a lecture format for the first five chapters, followed by five fully worked examples which could be used as case studies, to assist lecturers incorporate content on the topic area. We also sought endorsement by organisations such as CSIRO, the World Federation of Engineering Organizations and Engineers Australia. Unsolicited feedback from lecturers and students has been very positive with regard to both the value of the endorsement and utility of this format. For example, Associate Professor Roger Hadgraft, Director, Engineering Learning Unit, Melbourne School of Engineering, The University of Melbourne, Australia, and President of Australasian Association for Engineering Education wrote,[44]

> *'Whole System Design is a comprehensive resource to support professional, academic and student engineers in complex problem solving around sustainability – an area of focus recommended by the 2008 Review of Engineering Education in Australia: Engineers for the Future.'*

These and other similar reflections provided by colleagues in the field[45] support the literature which advocates the development of easily accessible and academically rigorous materials for immediate use by lecturers looking to integrate new content into the curriculum.

4.3.4.3 Energy Transformed

In 2007, in partnership with numerous other organisations, TNEP sought to develop three education and training modules (i.e. 30 lectures) in line with CSIRO's goal, '*to facilitate the development and implementation of stationary and transport technologies so as to halve greenhouse gas emissions, double the efficiency of the nation's new energy generation, supply and end use, and to position Australia for a future hydrogen economy*'.[46] We intended that these modules would provide a base capacity-building training program that would prepare engineers, technicians, facilities managers, and architects to address the issues of greenhouse gas emissions and work towards creating sustainable energy solutions throughout the course of their professional life. Within this context the modules would provide an introduction to integrated approaches to energy efficiency and low emissions technologies.

The resultant *Energy Transformed* education package contains 600 pages of peer-reviewed content, covering a wide range of issues related to energy for use in undergraduate education, providing industry, business and households with the knowledge they need to realise at least 30 percent energy efficiency savings as rapidly as possible. The text also provides an updated overview of the latest advances in low carbon technologies, renewable energy and sustainable transport.

This text was an important milestone in creating materials that could be published as a textbook and used directly as course notes, increasing the usability of the materials. It was also fully and freely available online, in contrast to the previously mentioned publications which were only partly available online. This project also highlighted several issues for me with regard to developing specialised content for universities. Firstly, the online format of this education and training program needs to be designed to make it easy for rapid uptake within the Australian higher education system (i.e. 1-2 hour lectures, medium-large class sizes, minimum preparation time). Secondly, buy-in by the educators themselves is essential for the materials to be used. This could happen through seeking trial of the material (as we did in 2004 with the introductory sustainability materials), offering financial incentives to trial (for example through honorariums), and recognising leadership in using materials in accreditation reviews.

4.3.4.4 Factor Five

Reflecting back to when TNEP first came together, we had not anticipated that in 2009 we would be working with Ernst von Weizsäcker with the support of Amory Lovins and Hunter Lovins, to update *Factor 4*. To facilitate use as a university textbook, *Factor Five*[47] was developed in two parts. The first presents a whole system approach to achieving up to 80 per cent resource productivity improvements across the major energy and water intensive industries (namely buildings, industry, agriculture, and transportation). The second part then presents reflections by Professor Ernst von Weizsäcker on his work with governments and industry over the past decade to prepare for a rapid transition to such improvements.

This experience provided an opportunity for me to reflect on how open-source content could embed and build upon knowledge and skills developed in other materials, to assist lecturers to provide deepening learning experiences for students without having to scaffold the material themselves. For example, the *Factor Five* publication builds on the whole system design approach outlined in *Whole System Design*. However, the reality of creating curriculum using this scaffolding approach was that it was very time consuming and labour intensive; an impediment often acknowledged in the literature.

4.3.4.5 Cents and Sustainability

In 2008, the team decided that a sequel publication was needed to accompany *The Natural Advantage of Nations*, which would highlight emerging knowledge since 2005, in particular with regard to strategic opportunities for reducing greenhouse gas emissions. In line with the 20 year anniversary of *Our Common Future*, we wrote *Cents and Sustainability: Decoupling Economic Growth from Environmental Pressures*.

Through this experience in writing about emerging dual track strategies for addressing environmental problems with my TNEP colleagues, I became aware of the similar need for a dual track approach for undergraduate and postgraduate education, to equip postgraduate students to contribute to immediate issues such as peaking greenhouse gas emissions by around 2025, while equipping undergraduate students with knowledge and skills for longer term challenges such as sustained reductions in greenhouse gas emissions between 2025 – 2050.

4.3.5 Content development and renewal – modules

While writing *The Natural Advantage of Nations* in 2003 – 2004,[48] our team realised that the content did not readily fit into the existing scaffolding of university engineering degree programs. Not only was the language of discussion foreign to current programs but core sustainability skill development in topic areas such as efficiency, whole system design, and sustainable design principles was minimal, if not absent, so it would be difficult for students to step into the textbook due to the level of assumed prior learning. Indeed, existing courses would need to be updated to accommodate this type of material. From the literature, we understood that creating modular content for new knowledge and skills is a popular mechanism, but which has a range of levels of success. Several experiences are discussed in the following paragraphs.

4.3.5.1 Introductory module content

Between 2002 – 2009, I participated in developing a number of portfolios of content, as summarised in Table 4-2. For the reflexive inquiry process, the *Engineering Sustainable Solutions Program* (ESSP) is discussed.[49] The overall goal of these modules was to explain how it is possible to engineer sustainable solutions fast enough on a global scale to bring humanity back within the ecological limits. The modules provided, for the first time in one place, a detailed overview of a range of relatively new insights, tools and strategies available to engineers to help them design for sustainability. Our team was able to obtain approval to attach a ‘Creative Commons Attribution’ copyright clause which enables any academic to freely copy and use the material as long as the source is acknowledged.

Table 4-2. Content resources developed by The Natural Edge Project

Content resource	Target audience*
'Sustainability Education for High Schools' as part of the 'Sustainable Living Challenge' (Supported by Griffith University and the Port of Brisbane Corporation) [12 lessons]	Technologies - Grade 10 Senior School Physics Senior School Chemistry
'E-Waste Education Courses', (Supported by Griffith University and DELL) [6 lessons]	Senior School HEI/ PD (Introductory)
Engineering Sustainable Solutions Program (ESSP) 'Introduction to Sustainable Development', (Supported by Engineers Australia, Society for Sustainability and Environmental Engineering and UNESCO) [12 lessons]	HEI/ PD (Introductory)
Engineering Sustainable Solutions Program (ESSP) 'Principles and Practices in Sustainable Development' (Supported by Engineers Australia, Society for Sustainability and Environmental Engineering and UNESCO) [12 lessons]	12 lessons: HEI/ PD (Introductory)
'Whole System Design: An Integrated Approach to Sustainable Engineering' (Supported by the Australian Federal Government Department of the Environment, Water, Heritage and the Arts) [10 lessons]	HEI/ PD (Intermediate)
'Sustainable IT: Reducing Carbon Footprint and Materials Waste in the IT Environment' (Supported by HP) [5 lessons]	HEI/ PD (Introductory)
'Sustainable Energy Solutions for Climate Change Mitigation' (Supported by the CSIRO and the National Framework for Energy Efficiency) [30 lessons]	HEI/ PD (Advanced)
'Sustainable Water Solutions for Climate Change Adaptation' (Supported by the Australian Federal Government Department of Climate Change) [30 lessons]	HEI/ PD (Advanced)

* HEI: Higher Education Institution; PD: Professional Development.
Source: The Natural Edge Project[50]

Several indicators highlight for me the success of these materials. First was the awarding of the full course and supporting book, *The Natural Advantage of Nations* the 2005 Banksia Award for Environmental Leadership, Training and Education. The work was also one of three finalists in the 2005 Australian Museum Eureka Prize for Sustainability Education. The full course has also been officially accepted as part of the United Nations Decade for Education in Sustainable Development. Colleagues have also provided valuable feedback on the need for such materials. For example, Head of the Department of Mechanical Engineering at the University of Zaragoga, Professor Luis Serra reflected in unsolicited correspondence that,[51]

> '*In respect to education on SD, and as a first step prior to a deeper integration into the programmes, we are promoting EESD … with specific courses ... without any doubt, we have found [the pre-prepared modules] useful in reducing time spent in generating and checking new content.'*

4.3.5.2 National pilot of introductory module

A key component of the ESSP content development was seeking to increase the use of such material through trialling it with a large number of institutions teaching engineering in Australia. In 2005, I led a trial of the Introductory Module,[52] following on from the initial pilot trial conducted at Griffith University by myself in 2004,[53] and building on from a trial by Mr Hargroves at the University of Colorado, Boulder.[54] In partnership with Engineers Australia, TNEP collaborated with 15 universities and TAFEs across the country to trial the module in first and second semester. Towards the end of each semester, the participants submitted a brief report summarising the review and/or trial experience and relevant recommendations or comments.

The multidisciplinary nature of the module was found to generate significant interest among students, with one respondent noting,

> *'The [Critical Literacies Portfolio] is innovative in that it is trying to ingrain a philosophy of sustainability into engineering students at the very beginning of their course, thus carrying that philosophy into all future learning… This program is a vital step in ensuring that engineers think about the impact that they command as designers and project managers.'*

However, due to the interdisciplinary and complex nature of the material, more time than originally anticipated was needed to adequately cover each unit, with another respondent noting,

> *'Many of the concepts (e.g. Factor 4) required greater time to explain than anticipated. Students appeared to have little prior knowledge on which to build understanding, this required time to be spent on regional and State-wide examples (e.g. brown coal, cheap electricity, aluminium production).'*

Qualitative evaluation of the students' learning in 12 universities indicated that the use of case studies greatly assisted the understanding of the students and their confidence in the role of the engineering profession in sustainable development as the case studies showed examples of solutions that already exist. An important characteristic of the content as noted by trial participants was the extensive review of literature conducted to ensure the material is rigorous and supported by known publications. Reference also to current media stories demonstrated the relevance of sustainability in engineering, stimulating interest in the content among students and trial lecturers alike. Comments on the style and structure from the trial participants were also positive with the flexible design of each unit regarded by trial participants as a useful format to assist the lecturer in adapting the material to suit their own needs.

Through this project, I learned that the module we developed was pitched at an appropriate level of detail to build students' awareness of the role of the engineering profession in delivering more sustainable engineering solutions, specifically those that take into account social and environmental impacts and their effect on the economic performance of the product or service. The module provided a sufficient mix of content and case studies across the disciplines (both engineering and non-engineering) to generate and maintain student interest, while effectively delivering the message that a whole of society approach is in fact required to deliver sustainable solutions. The structure and style of each unit was also effective in providing lecturers with the flexibility to utilise the material to suit their needs, thereby acting as a curriculum-enhancing tool as well as a course substitute. Due to the length of some units and the problems associated with exceeding lecture time, some key points needed to be combined or removed from lecture delivery.

4.3.5.3 Content development – undergraduate course

In 2005, the Queensland University of Technology's (QUT) Faculty of Built Environment and Engineering (FBEE) and TNEP (through myself and Mr Hargroves) embarked on a process of curriculum renewal, focusing initially on a first year common course to be offered to all first year undergraduate built environment students (approximately 1200) at QUT, titled 'Introducing Sustainability'.[55]

A significant part of the collaboration was the up-front engagement with key faculty to firstly generate a set of graduate attributes that address engineering and built environment professionals' requirements to deliver sustainable development, and to then prioritise and map which attributes would be addressed in the new first year course. This was scoped intentionally to provide a foundation that could then be expanded in the future to include mapping for other courses and other year levels. The generation of attributes, and subsequent prioritisation and mapping were undertaken in a workshop of 12 faculty members, over a period of four hours, facilitated by myself and Mr Hargroves. The participants comprised the team of lecturers likely to be involved with the first year course, the program convenor, and the lecturers from courses being amalgamated into the common course. The resultant list of attributes was provided to the new course convenor responsible for building the course, and the Faculty Dean for consideration in the larger context of the Faculty program offerings. This led to us creating a set of supporting notes for the course. The course has now been offered through three cycles and is now fully embedded in the faculty's programs, although the original content developed was used only for the initial year.

Having completed this project, I learned that appropriately facilitated (which may be external and professional) interaction with academics can be very successful and positive. This aligns with my experiences in my own institution. However, from anecdotal discussions with academics in the field about their experiences, there is a significant risk for inappropriate facilitation to lead to issues and problems, as this is a very personal process for academics. Once external advice and assistance is received, how the course is convened and prioritisation within the school will have much more of an influence over the success of the program than the initial content development process. The longevity of the developed content will still depend to a degree on the individuals involved and other institutional variables such as consolidation and learning and teaching strategies which may change over time.

This experience also aligned with literature on the power of student demand – in this case the student demand was overwhelming with more than 100 students (of the 800 student body) signing a petition to the Vice Chancellor requesting more sustainability content in their degree.

4.3.5.4 Content development – postgraduate course

In 2008, I worked with Mr Karlson Hargroves and the Louis Laybourne, Smith School of Architecture and Design (University of South Australia), to develop coursework units for the 'Master of Sustainable Design', drawing from and tailoring the open-source modules described earlier. These courses included 'Sustainable Design Theory - Sustainability and Society' and 'Sustainable Design Theory - Sustainable Design Principles'. The base material was edited and enhanced to align with the intentions of the graduate attributes for the new program, including a number of meetings with TNEP and staff from the School.

We attempted to plan these courses to be as modular as possible, to enable future flexibility in moving content around, and in adding to the content prepared. The pedagogy (i.e. layout and structure) of the text underwent minor improvements, including the better articulation of the learning objectives and with regard to the connection between the learning points and background reading. Seeing the resultant product on the course website, it was very satisfying to see the content being used, and enlightening to see how much of a difference some minor changes could make to the useability of the modular material. Head of School Professor Mads Gaardboe reflected to TNEP that, *'Basing two courses in our program on existing academically rigorous content has allowed us to fast-track our masters program delivery, reducing the time pressure on our staff to develop new curriculum, and ensuring students are exposed to the latest content in the field'.*[56]

4.3.6 Outreach to industry and professional organisations

Alongside my experiences as an early career academic, I was an active member of the Institution of Engineers Australia, and in regular contact with peers in industry; particularly in Queensland through former employment connections. As part of this reflexive inquiry process I have focussed on two initiatives that relate to industry outreach (website development), and professional organisations (in-house training).

4.3.6.1 Website development

From 2002, the education modules described above have been freely available through the TNEP website, as a self-paced learning tool on new and emerging knowledge and skill areas. In 2005, in collaboration with the EPA Sustainable Industries Division and the Queensland Division of Engineers Australia, I helped to create a web interface for introductory material on sustainable development. Over the following three years, our project team assisted the National Sustainability Taskforce with their strategic planning, a significant part of which was the development of a sustainability interface on the national website. The final product included direct links to more than 120 hours worth of TNEP training material, from introductory sustainable development content to energy efficiency, information technology issues, electronic waste and whole system design. Subsequently in 2009, the Australasian Association of Engineering Education also included links to the materials on their educational portal.

The emergence of the internet and free content as a significant opportunity for embedding new content into programs is discussed by numerous researchers in the higher education field from a variety of perspectives, such as Wiles and Littlejohn[57] (in the potential for e-learning in higher education), Heywood[58] (who comments on incorporating new technologies for teaching engineering education), and Mann *et al*[59] (in embedding sustainability into computing engineering). Unsolicited feedback to our research team from users indicates that it plays an important role. For example, one engineering student wrote from Sri Lanka, *"I am using the worked examples as assignment in the course titled 'Sustainable Development' for engineering undergraduates. Students have to study the assignment by themselves and present them in the class. It is an excellent aid for teaching sustainable development to engineering students who are not exposed to sustainability in any other engineering course".*[60] However, my journal entries, correspondence with team members during the development of the education modules, and my subsequent development of a protocol for using internet content[61] highlights the numerous problems associated with using content from the internet, including questionable integrity of the online information (e.g.

unbiased, substantiated/ proven), and stability of the online resource (e.g. changing internet addresses and document links).

In considering the application of such website interaction to the elements of curriculum renewal, there is clear potential for online resources to play a key role in both awareness raising, and facilitating content renewal and development. However, potential lecturer and student frustration with low quality and inaccurate information is a potential barrier to using the internet as a resource in the curriculum renewal process.

4.3.6.2 In-house training

I have been involved in co-facilitating a number of training programs with government and industry over the last 5 years, using the education modules described above, including with the Queensland Government EPA Sustainable Industries Division ecoBiz Program,[62] Townsville City Council Visioning a Sustainable Future – Capacity Building,[63] HATCH (Minerals Processing),[64] and KBR Internal Staff Training – Strategic Planning.[65] I have chosen to focus here on the KBR engagement for the reflexive inquiry process, due to the availability of detailed journal notes and documented follow up with our collaborating partner, as discussed below.

TNEP undertook a strategic planning workshop with key KBR managers in 2006 to consider preferred 'KBR competencies' with regard to sustainability knowledge and skills. As the then Sustainability Technical Sector team leader Bridget Kelly reflected,

> *'Selected KBR staff attended workshops, courses and seminars [which] resulted in the development of an in-house sustainability program through which we will educate and support our wider staff in the Asia Pacific region as the field of sustainable engineering continues to develop."*[66]

KBR's Asia Pacific Director of Engineering and Technology, Tom Connor, provided a cautionary note to academic institutions not considering such bridging opportunities,

> *'We are actively seeking collaboration with universities to keep our staff at the forefront of the latest innovations in sustainable development, but if the expertise or training are not around, then we cannot afford to wait – we will have no option but to develop the training in-house ourselves'.*[67]

Such industry experiences have been important for me in considering curriculum renewal opportunities related to bridging the gap in knowledge with industry. Regular contact with industry professionals through these initiatives confirmed the lack of understanding in industry with regard to emerging best practice and innovative technologies. These experiences confirmed the literature findings that university interface with industry through courses focused on the new content, can both assist

industry with knowledge and skill capacity building, but can also, for example, provide a potential recruitment stream for the institutions providing the outreach into masters programs. Furthermore, it highlighted that if universities do not start doing this soon they may miss out on mature age/professional students as industry trains in house.

4.3.6.3 Inter-departmental strategic planning

In November 2006, following the development of the E-Waste module, the Griffith University Department of Information Services (INS) invited me in my research role and on behalf of TNEP to contribute to their annual planning retreat, which included adding 'Sustainability' as a key consideration. In particular, INS senior management were keen to consider opportunities for further incorporating a tool developed by TNEP called the management helix for the sustainable organisation, or the 'Sustainability Helix', in their planning for departmental change towards sustainable operations.

I subsequently facilitated a 2.5 hour workshop with Mr Malcolm Wolski, the then Associate Director INS, which comprised two presentations to introduce the concepts of sustainability and e-waste, followed by a group activity. In 2007, INS undertook a follow-up second workshop with a small subset of senior management on strategic planning for sustainable operations, which I also facilitated.

A key learning for me from these two experiences was that within the university, there were significant groups of staff also considering sustainable operations, which could potentially link in with curriculum renewal initiatives on campus. I also confirmed the benefits of undertaking a highly structured process with a medium sized group of participants, to quickly arrive at an outcome that management can then take forward.[68]

Another key learning from these two experiences was a revelation during this process of reflexive inquiry, with regard to the potential application of the 'Sustainability Helix model shown in Figure 4-1 for rapid curriculum renewal. I had previously been involved in developing the Sustainability Helix between 2003 and 2006, as the TNEP research team explored organisational change models with a leading researcher and author in the field of sustainable practice, Ms Hunter Lovins (NCI Incorporated). The model is intended for organisations to undertake a concentrated process of significant renewal towards sustainable practice, after which they can return to continuous processes of review and action. In particular, the model considers six streams which were concluded to be integral to undertaking organisational change towards a sustainable organisation, namely: governance and management; operations and facilities; technical and professional capacity; human resource development and corporate culture; marketing and communications; and partnerships and stakeholder engagement.

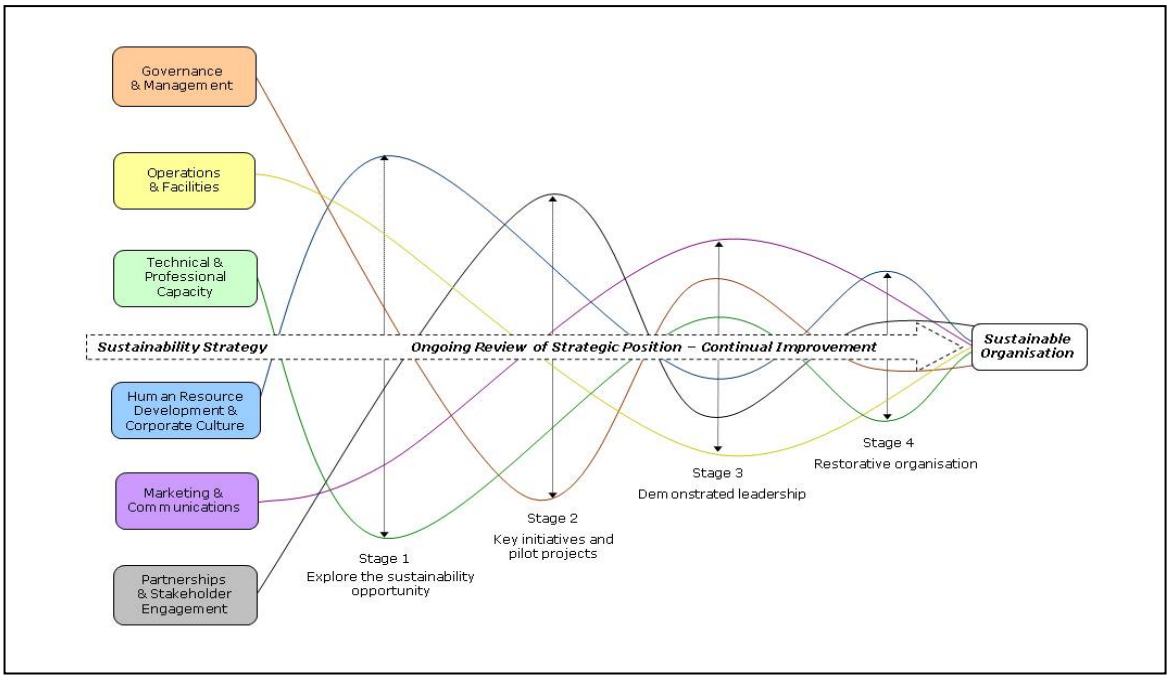

Figure 4-1. The Sustainability Helix for organisational change toward sustainable practice
Source: The Natural Edge Project (2005)[69]

The model involves strategically planning and progressing through several stages towards a sustainable organisation as follows:

- In Stage 1 of the model, an organisation considers options to determine what value 'sustainability' could bring to its mission and business model.
- In Stage 2 an organisation tests the business case for sustainable development through key initiatives and pilot projects.
- In Stage 3 an organisation makes a systemic commitment to behave responsibly towards the planet and society through its operation and influence. The organisation builds upon its responsibility to shareholder value by taking a public leadership role within industry, the community it operates in, and the world at large.
- In Stage 4 an organisation becomes a restorative company that restores human and natural capital, maximises shareholder value, and contributes to genuine progress in economic and social development locally and in the world at large.

Using this staged approach, the model helps organisations to address periods of intense change. Such a directional but integrated and flexible model provides a sense of autonomy necessary for change within organisational settings. It also highlights the complex and asynchronous nature of change, where staged implementation allows for sometimes random and sometimes fully planned interactions. The adaptation of this Sustainability Helix as a stylised representation for a unifying rapid curriculum renewal model is discussed further in Chapter 6.

4.4 Conclusions

In this chapter, a process of reflexive enquiry was used to reflect on personal project involvement, with the intention of reinforcing aspects that are already discussed in the literature, and also uncovering phenomena that may not be apparent in the existing literature on curriculum renewal. The narrative responded to a series of pre-determined questions about previous project experiences in the field as a lecturer and as a researcher.

In considering the questioning profile, there were a number of realisations about the practicalities of rapid curriculum renewal, in addition to some clarifications about the elements themselves, as presented in Table 4-3. Ticks are used to summarise those perspectives that reinforced the literature findings, while plus signs are used to highlight perspectives that add to literature findings.

Formal reflection on experiences as a lecturer highlighted the directional and systematic, yet dynamic and organic nature of rapid curriculum renewal, which will be unique for each institution. My learnings from the process supported the use of a directional and outcomes-oriented model for rapid curriculum renewal, which could be used in any institutional context to support further progress. I also learned that both my goals and frustrations as a lecturer very much reflected the frustrations and aspirations of other lecturers in this field that are documented in the literature. Realisations regarding barriers and opportunities were subsequently included in the emerging model for rapid curriculum renewal.

Formal reflection on experiences as a researcher helped me to understand the systemic learning that project experiences had provided, which provided rigour and rationale for what I had previously considered intuitive understanding. This was further enhanced through seeking comments on my documented learnings from a colleague also involved in each of the projects.

In conclusion, the review of personal experiences largely reinforced the literature findings, providing additional insight into some elements and highlighting the need for supporting requirements including timeframe catalysts, leadership and strategic planning. The review findings also aligned with the literature suggestion that a realistic timeframe for rapid curriculum renewal is in the order of two accreditation cycles. Finally, the review highlighted an existing model – the Sustainability Helix – which could be adapted to represent the process of rapid curriculum renewal. The model development is discussed further in Chapter 6.

Table 4-3. Summary of learning from the reflexive inquiry

Element	Lecturer perspective	Researcher perspective
Awareness Raising and Developing a Common Understanding	✓ *Staff awareness crucial* ✓ *Importance of peer network to encourage such professional development* ✓ *High level commitment critical*	+ *Formal off-campus professional development needs to be supported* + *Caution with ad hoc internet reliance, including questionable integrity of information*
Identifying and Mapping Graduate Attributes	✓ *Insufficient to have enthusiastic staff; longevity requires strategic planning within larger program*	✓ *Can range from an informal to highly structured process* ✓ *Upper management commitment is essential*
Curriculum Auditing	+ *Important to have a stable curriculum environment with School support for review* + *Without strategic insight, innovations may be removed as part of restructuring*	✓ *Curriculum auditing and review can be very confronting for staff* ✓ *A transparent process can motivate* + *Important to engage with staff directly – many innovations not documented*
Content Development and Strategic Renewal	✓ *Flagship modules need to be used carefully in the program* ✓ *Course criteria are critical (linked to attributes)* ✓ *Accessible and rigorous materials are important* + *Drop-in material needs to be highly flexible*	✓ *Modular content development time consuming and labour intensive* ✓ *Case studies greatly assist staff* + *Specialised content needs to be highly modular for ease of take-up* + *Buy-in critical for modular content to be used by lecturers*
Bridging and Outreach	✓ *Institutional support is important* ✓ *University content could be efficiently and effectively translated for high school and industry audiences* + *Logistics can be overwhelming* + *High school outreach is critical for recruitment to renewed program/s*	✓ *Critical to provide a scaffold for 'stepping up' to highly technical new and emerging content* ✓ *Inter-university collaborative offerings can provide a feasible interim or long term mechanism for delivering new courses* ✓ *Emergence of internet and free content is a significant opportunity for embedding new content into programs*
Campus Integration	✓ *Other campus departments are a strategic source of 'real' project/ assessment items* + *Submissions to senior management on campus opportunities can accelerate interaction*	✓ *Students are often vocal about the need for improved content* + *Significant initiatives likely already underway, which could link in with curriculum renewal*

Note: the following nomenclature: [✓] agrees with, and [+] in addition to, the findings of the literature review.

References

[1] Barnet, R. and Coate, K. (2006) *Engaging the Curriculum in Higher Education*, The Society for Research into Higher Education, Open University Press, England, pp7,9.

[2] MacDonald, B. and Walker, R. (1976) *Changing the Curriculum*, Open Books Publishing Limited, London.

[3] Nightingale, D. and Cromby, J. (eds) (1999) *Social constructionist psychology: A critical analysis of theory and practice*, Open University Press, Buckingham, p228.

[4] Desha, C. and Williams, P. (unpublished) 'Faculty Sustainability Forum - Signature grant – Environmental Sciences', internal report to Griffith University Science, Environment, Engineering and Technology (SEET) group, March 2005.

[5] Desha, C. (2004) '1084EVE Mechanics and Materials Course Outline', Griffith School of Engineering, Griffith University.

[6] Desha, C. (2004) Student Evaluation of Course (SEC) report from '1084EVE Mechanics and Materials', School of Environmental Engineering, Griffith University; Desha, C. (2005) Student Evaluation of Course (SEC) report from '1084EVE Mechanics and Materials', School of Environmental Engineering, Griffith University; Desha, C. (2006) Student Evaluation forms of the 3-week module for '1003ENG Materials and Design', School of Engineering, Griffith University; Desha, C. (2007) Student Evaluation forms of the 3-week module for '1003ENG Materials and Design', School of Engineering, Griffith University.

[7] Desha, C. (2004-2005) Personal journal notes for '1084EVE Mechanics and Materials', Griffith School of Engineering, Griffith University.

[8] Agronovski, I. (2004) '2114/2115EVE Design 1 Course Outline', School of Environmental Engineering, Griffith University.

[9] Williams, P. (2005) '1115EVE Professional Practice and Skills 1 Course Outline', School of Environmental Engineering, Griffith University.

[10] Desha, C. (2004) Journal notes for '2114/2115EVE', Griffith School of Engineering, Griffith University.

[11] Desha, C. (2004) 'Interim Report: Griffith Trial Summary, TNEP Trial of the Engineering Sustainable Solutions Program', Feedback Report to The Natural Edge Project, including class evaluation survey results.

[12] Desha, C. (2004) 'Interim Report: Griffith Trial Summary, TNEP Trial of the Engineering Sustainable Solutions Program', Feedback Report to The Natural Edge Project, including class evaluation survey results.

[13] Smith, M., Hargroves, K., Desha, C. and Palousis, N. (2007) *Engineering Sustainable Solutions Program: Critical Literacies Portfolio - Principles and Practices in Sustainable Development for the Engineering and Built Environment Professions*, The Natural Edge Project, Australia.

[14] Novak, J. (1990) 'Concept mapping: a useful tool for science education', *Journal of Research in Science Teaching*, Vol 27, No10, pp937-949.

[15] Lourdel, N., Gondran, N., Laforest, V., Debray, B. and Brodhag, C. (2004) 'Evaluation of student comprehension of sustainable development: use of cognitive map as indicator', *European Roundtable on Sustainable Consumption and Production*, 12-14 May, Bilbao.

[16] Lourdel, N., Gondran, N., Laforest, V., Debray, B. and Brodhag, C. (2007) 'Sustainable development cognitive map: a new method of evaluating student understanding', *International Journal of Sustainability in Higher Education*, Vol 8, Issue 2, pp170-182.

[17] Desha, C. (unpublished) Participation consent forms and completed mind-maps by 21 students, '2335EVE Sustainability Principles and Practices', Semester 2 2008, Griffith University.

[18] Lourdel, N., Gondran, N., Laforest, V., and Brodhag, C. (2005) 'Introduction of sustainable development in engineers' curricula: Problematic and evaluation methods', *International Journal of Sustainability in Higher Education*, Vol 5, Issue 3, pp254-264.

[19] Carew, A. and Mitchell, C. (2002) 'Characterizing undergraduate engineering students' understanding of sustainability', *European Journal of Engineering Education*, Vol 27, pp349-61.

[20] Segalàs, J., Ferrer-Balas, D. and Mulder, K. (2009) 'Conceptual maps: measuring learning processes of engineering students concerning sustainable development', *European Journal of Engineering Education*, Vol 33, Issue 3, pp297-306.

[21] Smith, M., Hargroves, K., Desha, C. and Palousis, N. (2007) *Engineering Sustainable Solutions Program: Critical Literacies Portfolio - Introduction to Sustainable Development for Engineering and Built Environment Professionals*, The Natural Edge Project, Australia.

[22] Desha, C. (unpublished) *2008 teaching journal - 1114-1115 and 1001ENG*, 2005-2009, evaluation report preparatory notes.

[23] Griffith University formal course evaluation reports for 1114/1115EVE (2005-2007), then 1001ENG (2008-2009).

[24] Griffith University (2007) '1001ENG-Nathan Campus-On Campus-Eng Practice', *2007 Student Evaluation of Course Report*, Question 13 and Question 15, 13 June 2007; Griffith University (2008) '1001ENG-Nathan Campus-On Campus-Eng Practice', *2008 Student Evaluation of Course Report*, Question 13 and Question 15.

[25] Yu, B. (2009) 'Head of School Presentation', Griffith School of Engineering Staff Retreat, 5 November 2009, Arundel Hills Country Club, Gold Coast.

[26] This conclusion is based on a qualitative assessment of evaluation forms (qualitative, open-ended questions) from the successive field trips.

[27] Desha, C. (unpublished) Teaching journal notes – NPI short course, entry on 14 October 2006.

[28] Through education for sustainability, the SLC program aims to encourage young people to raise awareness, engage minds and develop skills to be better able to respond to the challenge of sustainability in their future personal and professional lives.

[29] Desha, C. (unpublished) Email archives, 4155EVE/4207ENG and 7155EVE/7407ENG.

[30] Desha, C., Hargroves, K., Smith, M., Stasinopoulos, P., Stephens, R. and Hargroves, S. (2007) 'State of Education for Energy Efficiency in Australian Engineering Education—Summary of questionnaire results', report to the National Framework for Energy Efficiency, The Natural Edge Project.

[31] Desha, C. and Hargroves, K. (2009) 'Surveying the State of Higher Education in Energy Efficiency, in Australian Engineering Curriculum', *Journal of Cleaner Production*, Elsevier, doi:10.1016/j.jclepro.2009.07.004.

[32] Desha, C., Hargroves, K. and Reeve, A. (2009) 'An Investigation into the Options for Increasing the Extent of Energy Efficiency Knowledge and Skills in Engineering Education', report to the National Framework for Energy Efficiency, The Natural Edge Project (TNEP), Australia

[33] Desha, C., Hargroves, K., Smith, M., Stasinopoulos, P., Stephens, R., and Hargroves S. (2007) *Energy Transformed: Australian University Survey Summary of Questionnaire Results*, The Natural Edge Project (TNEP), Australia.

[34] McKenzie-Mohr, D., and Smith, W. (1999) *Fostering Sustainable Behavior: An Introduction to Community-Based Social Marketing (Education for Sustainability Series)*, Academy for Educational Development (co-publishers), Washington, and New Society Publishers (co-publishers), Gabriola Island, Canada.

[35] Hargroves, K., and Desha, C. (unpublished) 'Sustainability Desktop Audit: Faculty of Engineering, Bachelor of Engineering, Level 1 Curriculum', TNEP Final Report to Monash University, 14-15 November 2006.

[36] Desha, C., and Hargroves, K. (2008) 'Education for Sustainable Development Curriculum Audit (E4SD Audit): A Curriculum Diagnostic Tool for Quantifying Requirements to Embed SD into Higher Education - Demonstrated through a Focus on Engineering Education', *World Transactions on Engineering and Technology Education*, UNESCO International Centre for Engineering Education, Vol 6, No 2, pp365-372.

[37] von Weizsäcker, E., Lovins, A., and Lovins, H. (1997) *Factor Four: Doubling Wealth, Halving Resource Use*, Earthscan, London.

[38] Hawken, P., Lovins, A. and Lovins, L. H. (1999) *Natural Capitalism: Creating the Next Industrial Revolution*, Earthscan, London.

[39] McDonough, W. and Braungart, M. (2002) *Cradle to Cradle: Remaking the Way We Make Things*, North Point Press, San Francisco.

[40] Hargroves, K. and Smith, M. (2005) *The Natural Advantage of Nations: Business Opportunities, Innovation and Governance in the 21st Century*, The Natural Edge Project, Earthscan, London.

[41] Leading to the development of Smith, M. and Hargroves, K. (2010) *Cents and Sustainability: Securing our Common Future*, The Natural Edge Project, Earthscan, London. (www.naturaledgeproject.net/centsandsustainability.aspx)

[42] Lovins, A. (2003) Personal communications by K. Hargroves and M. Smith with Dr Amory Lovins, Director, Rocky Mountains Institute (RMI), July 2003, Boulder Colorado.

[43] Stasinopoulos, P., Smith, M., Hargroves, K. and Desha, C. (2009) *Whole System Design: An Integrated Approach to Sustainable Engineering*, Earthscan, London, and The Natural Edge Project, Australia.

[44] Hadgraft, R. (2009) Personal communications with Professor Roger Hadgraft, Director, Engineering Learning Unit, Melbourne School of Engineering, The University of Melbourne, Australia, and President of Australasian Association for Engineering Education (2007-2008).

[45] See http://www.naturaledgeproject.net/Whole_System_Design.aspx

[46] Energy Futures Forum (2006) *The Heat Is On: The Future of Energy in Australia*, CSIRO, Parts 1,2,3, www.csiro.au/csiro/content/file/pfnd.html, accessed 3 March 2007.

[47] von Weizsäcker, E., Hargroves, K., Smith, M., Desha, C. and Stasinopoulos, P. (2009) *Factor 5: Transforming the Global Economy through 80% Increase in Resource Productivity*, Earthscan, London

[48] Hargroves, K. and Smith, M. (eds) (2005) *The Natural Advantage of Nations: Business Opportunities, Innovation and Governance for the 21st Century*, Earthscan, London.

[49] Paten (Desha), C., Palousis, N., Hargroves, C. and Smith, M. (2004) 'Engineering Sustainable Solutions Program - Critical Literacies for Engineers Portfolio: Putting Sustainability as a "Critical Literacy" into Mainstream Engineering Curriculum', *International Journal of Sustainability in Higher Education*, vol 6, Issue 3, pp265-277.

[50] Unless otherwise stated, material is licensed under a Creative Commons Attribution 3.0 License.

[51] Serra, L (2008) Personal communications with Professor Luis Serra, Head of Department of Mechanical Engineering, University of Zaragoza, Spain, July 2008.

[52] Desha, C., and Hargroves, K. (2006) 'Critical Literacies Portfolio – Academic Trial Report', *Engineering Sustainable Solutions Program*, report to the Institution of Engineers Australia by The Natural Edge Project in Partnership with the Environmental College of the Institution of Engineers Australia.

[53] Desha, C. (2004) 'Interim Report: Griffith Trial Summary, TNEP Trial of the Engineering Sustainable Solutions Program', Feedback Report to TNEP, including class evaluation survey results.

[54] Hargroves, K. (2006) 'Report on the Boulder Trial', Several reports to the weekly team teleconferences, recorded in Desha, C. Journal notes.

[55] Hargroves, K. and Desha, C. (2006) 'Delivering Education for Sustainable Development in Urban Development, Design & Engineering Systems', TNEP Final Report, June 2006.

[56] Gaardboe, M. (2008) Personal communications with Professor Mads Gaardboe, Head of School: Art, Architecture and Design, School of Art, Architecture and Design, University of South Australia, 20 September 2008.

[57] Wiles, K. and Littlejohn, A. (2003) 'Supporting sustainable e-learning: A UK National Forum', Proceedings of the 20th Annual Conference of the Australasian Society for Computers in Learning in Tertiary Education. Adelaide, 7-10 December 2003.

[58] Heywood, J. (2005) *Engineering Education Research and Development in Curriculum and Instruction*, Institute of Electrical and Electronics Engineers (IEEE), Inc.

[59] Young, A., Muller, L., Mann, S. and Smith, L. (2009) 'Computing Education for Sustainability: Madrid and Beyond', *22nd Annual Conference of the National Advisory Committee on Computing Qualifications (NACCQ 2009)*, Napier, New Zealand, 28 February 2010.

[60] Shanthini, R. (2009) Personal communications through the 'Contact Us' section on the TNEP website, Mr Rajaratnam Shanthini, Engineering student, Sri Lanka, 25 September 2009.

[61] Desha, C. (unpublished) Internal web-search protocol document, The Natural Edge Project.

[62] Desha, C., and Hargroves, K. (2006) 'The Natural Advantage of Queensland's Industry (Natural Advantage Adult Learning Training Program)', Milestone 2 Post Workshop Report to the Queensland Sustainable Industries Division.

[63] Desha, C. and Hargroves, K. (2006) 'Introduction to Sustainable Engineering: a one day professional course for engineers', Townsville City Council Visioning a Sustainable Future – Capacity Building 1-week symposium, The Natural Edge Project, Jupiters Hotel and Casino, 6-10 March.

[64] Desha, C. (2005-2006) Journal notes from the HATCH Project.

[65] Desha, C. and Hargroves, K. (2006) 'KBR Sustainability Education & Capacity Building Framework Workshop: Workshop Outcomes', 4-5 August 2006, Post Workshop Report to KBR.

[66] Kelly, B. (2008) Personal communications with Ms Bridget Kelly, Sustainability Consultant, Halliburton KBR, 30 May 2008.

[67] Connor, T. (2008) Personal correspondence with Mr Tom Connor, Director Engineering and Technology, Asia Pacific Government and Infrastructure, Halliburton KBR, 12 August 2008.

[68] Desha, C. and Hargroves, K. (2006) 'Griffith University Senior IT Planning Workshop Sustainability Session: Sustainability Session Report', 17 November 2006, Facilitated by The Natural Edge Project.

[69] Hargroves, K. and Smith, M. (2005) *The Natural Advantage of Nations: Business Opportunities, Innovation and Governance in the 21st Century*, Earthscan, London, Chapter 10 'Operationalising Natural Advantage through the Sustainability Helix', pp161-164.

5. PEER REVIEW

In this chapter the formal peer review process and outcomes are discussed with regard to the emerging elements of rapid curriculum renewal, and the preliminary model. The chapter begins with an overview of the iterative review process, including how the reviewers were selected and the circumstances of the peer review, requests and timeframes. For each of the interactions, contributions are discussed with regard to how the preliminary findings were subsequently refined with these perspectives to develop the preliminary model for rapid curriculum renewal. This includes the evolution of thought about the problem, changes made to the model and elements, and additional questions that needed to be addressed to better understand the concept of rapid curriculum renewal in urgent and challenging times. Following the personal narrative approach in Chapter 4, this chapter continues to use the personal pronoun.

5.1 Peer review of emerging elements

Following the identification of a number of elements of curriculum renewal that can assist rapid curriculum renewal from the literature (see Chapter 3), these elements needed to be tested for confirmability among the target audience of international engineering educator community. Given the limited budget available, a workshop format (i.e. a form of focus group) was considered to be a useful feedback mechanism to ensure that at this stage of the research, I was accurately targeting issues and potential opportunities.

A number of international engineering education conferences were identified which could provide a ready participant pool of potential reviewers, providing access to ‘mainstream’ practitioners who may or may not have been exposed to education for sustainable development previously. Further to enquiries with various conference organisers about potential collaboration to host workshops at their events, and considering the timing and location of conferences, two international engineering conferences were shortlisted, both held in Melbourne in December 2007, and both of which accepted the peer-review workshop proposal.

Table 5-1 summarises the peer review interactions, which are discussed in the following sections. Both workshops were advertised by the conference organisers within the proceedings (i.e. at no additional cost to the conference delegate) and each workshop took place in a seminar room at the conference venue. All participants were asked whether they gave permission for their participation in the workshop to contribute to research underway, and for their contribution to the workshop to be recorded for

note-taking purposes, following which the audio would be deleted. There were no objections from participants in either workshop.

Table 5-1. Summary of peer review interactions regarding emerging elements

Workshop 1: 2007 iCEER Conference Workshop	Workshop 2: 2007 A2E2 Conference Workshop
– 7 December 2007, Victoria University – 12 participants (international composition) – Interdisciplinary, self-selected (advertised) – Written feedback and focus group discussion	– 12 December 2007, University of Melbourne – 9 participants (international composition) – Interdisciplinary, self-selected (advertised) – Written feedback and focus group discussion

In each workshop, participants were given 15 minutes to peruse a summary paper of the elements of rapid curriculum renewal. Then, for each element the participants were asked to respond in a group discussion to the questions: 1) Is there anything missing or confusing about this element that you would like clarified?; 2) Do you have an experience of this element of rapid curriculum renewal that you would like to share?; and 3) What cautionary advice would you give to the researchers regarding this element? Finally, the participants were asked for their comments on whether there is a preferred structure for how the elements should be addressed in urgent and challenging times.

5.1.1 2007 iCEER Conference Workshop

On 7 December 2007, my colleague Mr Hargroves and I facilitated a full day workshop on 'Elements of Curriculum Renewal to Embed Sustainability into Engineering Education' at the 2007 International Conference on Engineering Education and Research.[1] This workshop comprised both awareness raising and delegate participation in critiquing curriculum renewal elements, considering: the current state of engineering education for sustainable development; embedding sustainability principles and practices into engineering education (including provision of materials for immediate use); and approaches to accelerating transitions to engineering education for sustainable development.

In the final session, I facilitated a 1.5 hour peer-review process with twelve engineering educators from Australia (6), America (2), Malaysia (1), New Zealand (1), Thailand (1), and the United Kingdom (1). The participants read and discussed a summary paper of the emerging elements[2] for the first 90 minutes, addressing the three pre-set questions

(described above) for each element in the order it was presented in the paper. Given my interest in seeking feedback on the audit element in particular (which had been explored through project experiences as discussed in Chapter 4), participants then undertook an individual written critique of a paper on the curriculum audit tool[3] for a further 30 minutes.

The following paragraphs summarise the participants' considerations (using their terms and expressions)[4] and my reflections on how this feedback affects the emerging elements.

- *Awareness raising activities:*

  The participants questioned whether this item referred to both awareness raising among staff as well as students. Several participants provided examples of where their department had undertaken awareness raising activities for staff and students, including public debates. There was discussion about the reality that some staff are apathetic and that awareness raising may be fruitful to a point, where people will not attend because they believe they have heard it all before. One participant asked about whether resources were commonly available at the faculty level to have such awareness raising events. Another participant noted that awareness raising is the first step, but will not change behaviour on its own.

  Reflecting on these discussions I realised that based on the literature findings, the awareness raising element needs to be clearly worded to define the primary audience as staff rather than students, to create a common understanding about sustainability and sustainable development in a form of professional development. The discussion also highlighted the need to better explain that awareness raising among students is intended to be achieved as an outcome of the rapid curriculum renewal process, however, I realised that student involvement in awareness raising initiatives could also be another way to accelerate the learning by both staff and students. There was also a need to acknowledge the resourcing implications for awareness raising activities, and that this step formed a significant first step in a transition to EESD.

- *Scoping workshops with key staff:*

  Participants sought clarification about how this element differs from the first. With regard to scoping learning outcomes and graduate attributes, one participant commented that,

  'all courses tick off against graduate attributes. My experience shows that either 10 percent who are interested will attend but not enough to make a

change, or the majority of people will attend and fudge their way through the process to get back to their work'.

The same participant noted that where change happened, it was due to employers wanting practical experience which had then caught the attention of senior management and program convenors. With regard to scoping staff expertise and interests in sustainability related topics, one participant noted that staff get asked about their research interests when they join a university, but not after, so it could be interesting to ask staff regularly as their interests may change.

Reflecting on these discussions I realised that this scoping element was still quite broad, resulting in quite different responses from participants ranging from research interests to graduate attributes. This element also needed to be better differentiated from the 'awareness raising' element. Looking back at the literature review findings, I realised that this element was really highlighting the need to focus on reviewing and/or developing clear graduate attribute statements related to EESD for engineering programs, to provide a well-considered platform for course renewal options. In particular, this element needed to highlight the importance of a timely rigorous, inclusive, transparent process for determining and monitoring the desired graduate attributes, to result in meaningful targets that staff will take ownership of.

- *Desktop Audit and classification of programs:*

In discussing this element – and also in the written feedback on the audit paper – participants expressed their interest in such a tool which could assist in documenting where in the curriculum sustainability is taught, and where improvements need to be made. A number of minor amendments were made to the paper, but no substantive content changes were recommended regarding the audit process. A number of participants did note the sensitive nature of auditing curriculum, where the courses are strongly attached to an individual staff member's sense of self and worth.

These participant contributions confirmed the literature findings with regard to the importance of this element for rapid curriculum renewal. However, it became apparent that this element relies quite heavily on the success of the 'scoping' element, where staff determine the desired graduate attributes and then map where they are developed within the program. Once the scoping task is completed, an audit can determine whether the attributes are indeed developed in the designated course/s and where improvements can be made. I also realised that more acknowledgement was needed with regard to the sensitive nature of the auditing

process and the subsequent need for a rigorous and inclusive process that engages with staff rather than distancing them from management.

- *Curriculum - existing course renewal (Integrated approach):*

Several participants considered that they were already using an integrated approach to their course development. There was some discussion about the frustration of colleagues not wanting to participate in broadening the sustainability experience to their courses. One participant noted that many of their colleagues want a senior figure to tell them what to do so that they can complain to that person, rather than taking the initiative to do it themselves. The participants spent some time agreeing that rather than being just about displacing subject matter, curriculum renewal should be about showing how current content is also relevant. According to one participant, in creating new course content,

> *'… the bigger problem is that engineering education has no sense of final product – no ideology. Historically, engineering was linked to economic performance. Since the late 60s, engineering has been linked to humans. We need to link engineering to sustainability, which is happening at my university'.*

Another participant noted that whereas the flagship approach can become quite constrained in meeting accreditation preferences (*'sacred cows [i.e. sacrosanct areas] in the content that can't be changed'), '… in an integrated approach you can hide content in the course'*.

Reflecting on these discussions I realised that in a short space of time the participants had expressed a clear sense of frustration that colleagues were not participating in an integrated curriculum renewal process. Moreover, I realised there was a perceived need to use an integrated approach to 'hide' sustainability content within the curriculum to enable it to be taught, which I had not previously identified from the literature, but which on review was present in the subtle use of language in titles and within the substance of papers (for example using terminology such as 'blending', and through substituting readings and lecture notes without changing course learning outcomes or assessment). Hence, this element needs to highlight the minimally disruptive intentions of an integrated approach to rapid curriculum renewal. In addition this element could also be used to efficiently incorporate the identified graduate attribute development requirements within the program.

- *Curriculum - new course development/ replacement (Flagship approach):*

  The participants spent some time agreeing that first year engineering was largely about teaching the critical fundamentals, with not much room to move, except for the course in most programs that is allocated for teaching professionalism, ethics, safety and other emergent topics required by accreditation agencies. One participant noted that an existing barrier is perhaps that courses are already agreed to with accreditation bodies. Another participant commented on institutional resistance to such a concept,

  > *'We may need to take a revolutionary approach - a flagship approach - to draw interest, but my university is very bureaucratic'.*

  Several participants discussed how the professionalism/ ethics first year course included sustainability content, as directed by the university or an outside accreditation board. For example, the National Accreditation Board of Malaysia found no environmental science in their program, so subsequently all university students must do an environmental science course. At another university all students in the engineering faculty must take a 'Health Safety and Environment' course, or an interdisciplinary social science course.

  These discussions about the 'flagship' element confirmed for me the need to highlight the role of flagship courses in EESD. The participants' discussion aligns with the literature which suggests that this is already a popular mechanism for incorporating sustainability content within the program.

- *Outreach and bridging:*

  To begin with, the participants did not have many questions or comments regarding the element's explanation. Then one participant queried whether the outreach and bridging could be extended to industry in the form of continued professional development. This question was followed by some discussion among most participants about how industry is increasingly asking for short courses to train their staff in sustainability related topics. Another participant asked whether outreach also extended to the operations of the university, to bring in the 'greening campus' initiatives that were gaining popularity internationally.

  Through the short discussion, I realised that this element was currently too shallow in description, making it difficult for the participants to think about it in detail. It did not acknowledge opportunities, discussed in the literature and by the workshop participants, around engaging with industry through short courses, advisory boards and committees, and through guest lecturers. In addition, bridging activities such as

short courses are more closely aligned with normal teaching than outreach, which may involve school visits and guest lectures. Hence, 'bridging and outreach' may be a better phrasing of the element.

Furthermore, in looking back at the literature review findings, I realised that there was another element that I had not previously identified within the grouping of mechanisms for rapid curriculum renewal; namely the integration of course work with what is happening on campus i.e. 'campus integration'. This area of consideration has a wealth of literature on experiences in Australia and overseas, which I had previously disregarded due to my perception of it being about campus operations (i.e. facilities management).

- *Structure of the Elements:*

The participants did not have immediate thoughts when asked about the structure of the elements, which were presented in bullet points in the paper, and tabulated for discussion in the workshop. One participant then noted that the Engineers Australia requirements for what could and couldn't be modified within programs were already quite detailed. There was then discussion about frustrations with regard to the layers of bureaucracy within each of the participants' universities, and the subsequent low likelihood of anything prescriptive or too detailed being taken on board. One participant commented that it was more likely that a program convenor might take a model on rapid curriculum renewal, select parts of the model that suit the context, and then adopt those parts as they fit. By this stage the participants had relaxed considerably into the workshop and there was a short period of multiple conversations about similar perspectives between various participants.

This conversation and subsequent further reading in the literature on curriculum renewal processes helped me to understand the potential for a dynamic, complementary role for a model that assists engineering educators with rapid curriculum renewal. As discussed in Chapter 3, the resulting model does not contradict any of the existing models for curriculum renewal documented in the literature, it merely identifies mechanisms for dealing with timeframe considerations when time constraints exist. Hence, the model evolved from a bullet point list of elements for consideration, to a diagrammatic representation of the time-related elements that can help manage the curriculum renewal process within a short timeframe.

5.1.2 2007 A2E2 Conference Workshop

On 12 December 2007, my colleague Mr Hargroves and I facilitated a workshop on 'Emerging Engineering Education Curriculum for Sustainable Development' at the Australasian Association of Engineering Education Conference.[5] Running over a full day with 23 participants in total, the workshop began with an explanation of curriculum materials available for immediate use in engineering programs. In the final session, I facilitated a 1-hour discussion of the elements using the same paper as for the previous workshop,[6] with 9 participants from Australia (6), New Zealand (2), and America (1). I began the workshop with a summary (using PowerPoint slides) of the elements, noting amendments that I had made from the first peer review workshop. As one of the workshop participants (from Australia) was also present at the previous workshop they did not contribute to discussions except to assist me in accurately recalling contributions from the first workshop. The participants' contributions and my reflections are summarised as follows, where discussion that is similar to the previous workshop has been paraphrased for brevity:

- *Awareness raising activities:* There was general agreement among the group about the element, and there were no comments regarding additions or modifications to this element. Two participants provided examples from their own institutions where awareness raising activities had been undertaken. I concluded from these discussions that this element now addressed the questions by the first workshop group. Furthermore, the element was now self-explanatory.
- *Scoping workshops with key staff (graduate attribute mapping):* Several workshop participants commented that they thought this was an important component of strategically improving curriculum and there were no additional comments. I concluded from this short discussion that this element was now also self-explanatory.
- *Sustainability desktop audit:* There was some discussion agreeing that undertaking an audit within a department can be difficult due to the sensitivity of staff having their courses reviewed. In spite of this, there was general consensus that an audit would also form an important part of timely curriculum renewal. Reflecting on this discussion and the literature review findings, I concluded that this element would likely resonate with educators as a particularly challenging but important part of a rapid curriculum renewal process.
- *Curriculum – existing course renewal (Integrated approach):* Workshop participants provided several examples of curriculum renewal within their own courses. They agreed with the previous workshop participants that it was difficult to get other staff

enthusiastic about integrating content across more than one or two courses. No further comments were made on this element. From this discussion I concluded that this element would be readily identifiable but potentially challenging for engineering educators to incorporate.

- *Curriculum - new course development/ replacement (Flagship approach):* Workshop participants agreed that this was the most popular option with their departments, however, there was frustration voiced by two of the participants that once the flagship course was complete, nothing more was planned for integrating sustainability content. There was some discussion about the need for such flagship courses to be accompanied by integration of the new content across the discipline. This then progressed to a discussion about some departments trying to create a new 'bachelor of sustainability' as a separate niche program to mainstream engineering. There were a variety of opinions about whether this was a good idea. I realised in reviewing the quite different workshop discussions for this group and the previous group that the flagship and integrated discussions belonged to an overarching element of 'curriculum development and renewal', with many permutations of strategic renewal and new content development possible. This grouping of the mechanisms under one element also represented the literature surrounding content development options more closely.
- *Bridging and outreach:* The workshop participants agreed with the need to include industry outreach within this element, to recognise the potential for professionals demanding short courses and masters courses on sustainability topics to drive their timely integration into engineering postgraduate programs.
- *Campus integration:* This new element presented to the workshop participants was well received, with the participants collectively agreeing that it was an important component of a strategic approach to integrating sustainability content into the curriculum. Specifically, students could be provided with 'real' project opportunities on campus, and lecturers could also have 'hands on' experience in applying sustainability theory.
- *Structure of the elements:* Participants mostly agreed with the comments provided by the first workshop group, with one participant noting the need for a buffet approach to the model, where program convenors and heads of schools can, *'put what they want on their plate'*. The model needs to be as flexible as possible, serving to provide ideas for engaging in rapid curriculum renewal, rather than being a prescriptive *'woe to go'* method. However, there was agreement by a few participants that actually, a prescriptive option would be very well received by their

department, as they had no idea what to do. This discussion provided supporting evidence for me to develop a very flexible model that contained detailed descriptions of the elements and their potential application, in order to assist the full spectrum of potential users within the engineering education field.

5.1.3 Summary of outcomes

Further to feedback from the two peer-review workshops, I revisited the literature and discussions for insights as to how best to clarify the elements into more autonomous elements that could be of benefit to departments considering timely curriculum renewal. This process resulted in the following revisions to the preliminary set of elements, which was subsequently incorporated into the updated literature review (Chapter 3):

- The element called 'Awareness raising' was reworded to be 'Awareness raising and developing a common understanding'.
- The element 'Desktop Audit and Classification of Programs' was split into two elements comprising: 'Identifying and mapping graduate attributes', and 'Curriculum auditing'.
- The two elements describing curriculum renewal (i.e. 'Curriculum - Existing Course Renewal (Integrated Approach' and 'Curriculum - New Course Development/ Replacement (Flagship Approach)') were consolidated to an overarching element called 'Content development and renewal'.
- A new element was added to the set, called 'Campus integration'.

A number of minor amendments made to the description of the elements as discussed above, were incorporated into Chapter 3. In addition, the linear, tabulated approach to the elements (as shown in my earlier papers and presentations on the topic) was reconsidered into a 'halo' representation, whereby the elements became more autonomous features of rapid curriculum renewal, which could be used in part or in entirety to undertake the transition to EESD, depending on the context of the individual department.

5.2 Peer review of preliminary model

Following the process of reflexive inquiry into personal project experiences (see Chapter 4), another set of peer review interactions were planned, to confirm the validity of additional findings and interpretations with regard to the elements and the emerging model. As for the earlier peer review, given the limited budget available, a low-cost method was necessary. However, as more detail was sought for this review process, written reviews were considered preferable. In addition, input from experts in the field was considered important at this stage, given the depth of considerations for each element and the importance of situating the model properly within the engineering education system.

With this in mind, journal publications were examined to determine which of them received the most in-depth review as part of the journal peer-review process, and thus potentially provided access to expert peer reviewers in the field. Subsequently, one journal in particular – the *International Journal of Sustainability in Higher Education* (IJSHE) – appeared to have the most relevant publications on the topic. In communication with the Editor of the *International Journal of Sustainability in Higher Education (IJSHE)* in 2006-2007, I prepared 6 papers on the elements of curriculum renewal, as the lead author in liaison with Mr Hargroves and several other colleagues, which were intended for inclusion in the journal as a special issue publication on the topic of rapid curriculum renewal.

Table 5-2 summarises the drafted papers which cover the substance of the proposed preliminary model on rapid curriculum renewal and therefore provided a robust mechanism for seeking independent academic validation of the substance of the study. Table 5-2 also notes the corresponding chapters that have incorporated parts of the papers (reworded and restructured), including refinement of the content through the peer review process. Subsequent papers and articles are attached in Appendix A.

International conferences were also reviewed for the potential to deliver a presentation and facilitate a workshop on the research, with engineering educators who were specifically considering the topic of EESD. Of the conferences available, the International Conference on Engineering Education for Sustainable Development appeared to be the most suited for this phase of peer review, where it could be expected that reviewers would most likely have a keen interest in the topic and varying levels of experience in embedding sustainability into the engineering curriculum.

Table 5-2. Drafted papers, publications and corresponding chapters

Drafted papers and subsequent publications	Dissertation content
An appraisal of the rationale for curriculum renewal for engineering education for sustainable development *Publications:* In 2007 two papers were presented on the topic at an internal Griffith University faculty research conference.[7,8]	Chapter 1
The engineering educator's imperative: addressing the time lag dilemma in curriculum renewal towards engineering education for sustainable development *Publications:* In 2009, a modified version of this paper was accepted for publication by IJSHE.[9]	Chapters 1, 6
Raising awareness, identifying and mapping graduate attributes to assist curriculum renewal towards engineering education for sustainable development *Publications:* In 2009, this paper was reworked into two chapters for a UNESCO publication (in press).[10]	Chapters 3, 4, 6
Education for sustainable development (E4SD) curriculum audit as a tool for planning the transition to education for sustainable development *Publications:* In 2007 a paper was published on the curriculum audit in UNESCO's *World Engineering Transactions.*[11]	Chapters 3, 4, 6
Embedding sustainability into engineering curriculum: niche degrees, flagship or integration? *Publications:* In 2004, a paper discussing the merits of modular open-source course development was presented to the 2004 Engineering Education for Sustainable Development conference in Barcelona (Spain) and this paper was subsequently published in 2005, in the *International Journal of Sustainability in Higher Education*.[12] In 2007 as part of the paper development, a summary paper was presented to a national IDC conference on Engineering and Training,[13]	Chapters 3, 4, 6
Reviewing the state of engineering education for sustainable development: an overview of the global context and key findings of an Australian survey on energy efficiency education *Publications:* In 2009, a reduced version of this paper was accepted for publication in the *International Journal of Cleaner Production*.[14]	Chapter 4

This workshop would be useful to seek feedback on the final draft of the papers being prepared, where the opinion of experienced practitioners in the field would be valuable in identifying potential difficulties and gaps within the proposed elements of rapid curriculum renewal. Subsequently, my proposal to present a keynote at the conference and then facilitate a peer review workshop of the 6 papers was accepted.

Table 5-3 summarises the peer review interactions, which are discussed in the following sections.

Table 5-3. Summary of peer review interactions regarding an emerging model

Peer review interactions	Details
Written Correspondence	– Invited open peer review from professional network – 32 peer reviewers on 6 drafted papers (international) – Written correspondence (e-mail), verbal feedback (phone)
Workshop (EESD08)	– Invited open peer review from conference delegates (EESD08) – 12 participants (international) – Mostly verbal feedback, some written feedback (annotated papers)
IJSHE Journal Reviews	– Double-blind peer review from international advisory board – 12 reviewers on 6 drafted papers (international) – Written correspondence (via journal editor)

5.2.1 Written correspondence

During the paper preparation period 2007-2008, I sought peer-review of the drafted 6 papers through written correspondence with 32 international educators in the field. These reviewers were identified and invited from published papers, conference presentations, and through referral (as acknowledged in the Declarative). Table 5-4 summarises the background demographics of the peer-reviewers with regard to their place of employment. Table 5-4summarises regional representation.

Table 5-4. Demographic details of the 32 peer reviewers, by sector

Sector Representation	Number of Peer-Reviewers
Academia – Staff	23
Academia – Students	2
Industry	3
Professional Organisation	4

Table 5-5. Demographic details of the 32 peer reviewers, by country

Sector Representation	Number of Peer-Reviewers
Australia	9
Europe (Austria, Netherlands, Spain, Sweden)	8
America	5
United Kingdom	4
Mexico	2
New Zealand	1
Malaysia	1
China	1
Africa	1

Comments from these individuals were used to strengthen the text of the 6 drafted papers, with specific contributions (in the form of ideas or quotes) referenced accordingly, and acknowledgment where contributions had been made by other authors. Key learnings from this review process included the following:

- A number of examples using the elements were discussed, that were not fully documented in the literature, but for which the corresponding educators were able to provide additional anecdotal evidence of progress. I appreciated that this check-in with authors of papers is an important validation mechanism when discussing emerging trends and learning.
- For countries where English is not the primary language, terminology around engineering education, sustainable development and rapid curriculum renewal may be challenging. I realised that my writing needed improvement for clarity in a number of areas, to have the potential for use internationally.
- There was a significant amount of encouragement from corresponding educators, regarding the need for the notion of rapid curriculum renewal to be discussed and acted upon. This aligned with the sense of frustration at current practice, evident in the literature, and the increasing calls for action.
- There is a growing disconnect between engineering and science, where the majority of practicing engineers (as opposed to those who are in the public spotlight) may have quite a different view of technology and sustainability, seeing new and emerging knowledge and skills as a threat.

5.2.2 Workshop (EESD08)

In September 2008, I delivered an invited keynote paper to EESD08, on 'Mainstreaming EESD – Elements of Rapid Curriculum Renewal' on the morning of the third day,[15] and then facilitated a 2-hour workshop in the afternoon on 'Accelerating Curriculum Renewal - Behaviours, Barriers and Benefits' which formed part of the conference program. Twelve conference delegates (Austria (3), Mexico (1), Japan (1), Spain (2), Netherlands (3), and America (2)) decided to attend the workshop from a total conference attendance of approximately 110, which the conference organisers commented was a very good representation, given the 8 concurrent sessions being held on the third and final day. The participants voiced their preference for reading about and commenting on papers additional to my keynote (which was essentially paper 2) given the limited time available. Hence, Paper 2 was not discussed in the workshop, and I relied on the question and answer session following the keynote address.

Seated at 5 tables (i.e. one for each of the remaining papers), delegates were asked to first read a paper for 30 minutes, then discuss within their group for 20 minutes three questions: 1) what is unreasonable about the paper?; 2) what is missing from the paper?; and 3) what in the paper should be taken (i.e. discussed) further by the authors? Delegates then presented a summary of their discussions to the rest of the workshop, followed by a whole of group discussion. I facilitated the discussions without providing any personal input on the content, to ensure all comments were recorded and that all participants were able to contribute.

The following paragraphs summarise participant contributions during the various group presentations (noted by participants on butchers paper), and my subsequent revisions to the elements and model. Notes about the amendments made were emailed back to the participants in October and no participant required clarification or further amendments to be made.

Paper 1 Workshop Comments (Appraisal of the rationale for rapid curriculum renewal in engineering):

The participants commented that the description of the elements was largely a top-down approach to curriculum renewal, after which followed a discussion on whether this was the case. I realised that this observation regarding whether the issues and solutions involve top-down/ bottom-up mechanisms was not yet addressed in the model, and subsequently included text regarding the pressures being both top-down and bottom-up in Chapter 1 text on increasing pressure for curriculum renewal towards EESD. I also included text regarding the elements themselves being a mixture of top-down, bottom-up and middle-out mechanisms to address curriculum renewal.

Participants commented that there was *"Little outside the 'anglo' world"* in the text. Unfortunately I could not find much literature in English to reference from Asia, Latin America, or Africa on this topic. I subsequently found several more English references from these regions to support the discussion.

Paper 2 Comments (Conference and Workshop) (Addressing the time lag dilemma):

In the absence of a participant group focusing on this paper in the workshop, I had to rely on comments provided by delegates following the keynote address, either in front of the audience or after the session directly with me. One of the comments provided with regard to the time lag dilemma was that, *'It could have been even more provocative, in recommending transformation'.* Reflecting on this feedback in the context of the specialised nature of the conference, I concluded that this was a good

indication that the elements are appropriately derived and 'mainstream', providing a practical and pragmatic approach to rapid curriculum renewal.

A delegate also commented, 'I would like to see an extension of the timeline on the SCR/ RCR graph, to 2040, showing that graduates will only just be reaching decision making positions by then'. I realised that this implication could be discussed further and hence this aspect was added to the time lag dilemma considerations (Chapter 6).

Paper 3 Workshop Comments (Raising awareness and identifying and mapping graduate attributes):

There were several participants who thought that the scenario of a department considering rapid curriculum renewal was not realistic within their department, while others considered it to be quite reasonable. I realised that for departments who have not committed to EESD, the notion of rapid curriculum renewal towards EESD might appear quite foreign. The model did not yet acknowledge that it is intended for those departments who have already made a commitment to EESD. I have subsequently added this into the model description (Chapter 6).

All workshop participants agreed that rapid curriculum renewal relied to some extent on the buy-in of the students; a point which was not yet clear in the paper. I realised that this was a perspective that needed to be included within all of the elements and subsequently included text regarding the importance of student and industry consultation prior to key decisions such as the graduate attribute mapping workshop.

Participants also discussed whether rapid curriculum renewal is specific to EESD, or rather an issue for other disciplines as well. All agreed that the focus should first be on their own discipline of engineering, which could then be shared with other disciplines. I concluded that this unprovoked discussion about the possible relevance to other disciplines was a good indication of the potential for the RCR research to be considered elsewhere.

All workshop participants agreed immediately that the paper correctly highlighted a need for accreditation to act as a more powerful driver. This helped to confirm for me a growing realisation that rapid curriculum renewal is heavily affected by the strength of accreditation requirements.

Paper 4 Workshop Comments (Curriculum auditing):

The workshop participants agreed that the student perspective could be made stronger in Paper 4. I subsequently included a statement in the 'audit method' section to

acknowledge the potential benefit of including student feedback as part of the audit process. Further to the workshop, two papers were also forwarded to me, on an audit tool developed in Wales through the BRASS Centre, which I subsequently included in the literature review.

Specific comments by the workshop participants about the auditing tool included, '[The tool] will be useful to help departments who are committed/ interested in sustainable development', 'Assessment of 'embedding sustainable development' (which is quite intangible and difficult to assess) – helps the department to point out strengths and weaknesses', and 'The process of internal and external assessment is beneficial'. These comments concurred with other peer review which suggested that the audit tool could be of immediate and practical use to engineering educators.

Paper 5 Workshop Comments (Curriculum development and renewal):

The participants spent some time discussing whether a full 'armada' of supporting courses is needed to begin the process of rapid curriculum renewal. They discussed the potential to begin with a flagship and a few support vessels then grow, and what critical mass is necessary with regard to flagship and armada courses. I concluded from these discussions that the questions were important in themselves, as the answers would depend on the curriculum context. Subsequently, text regarding these questions was added to the text.

Paper 6 Workshop Comments (Energy efficiency survey):

A few of the participants commented that more students might actually be reached outside of the classroom, through campus experiences. I realised that these comments aligned with other documented frustration among the student body that curriculum renewal is not happening fast enough, concluding that these comments reinforced the need for action, and the potential usefulness of the element regarding campus integration.

Participants also discussed the challenge of the 'not invented here' syndrome where, if academics have not developed or contributed to an innovation themselves, then they won't use it. A number of participants voiced their frustration that this occurs. They also spent some time discussing the need for other stakeholders to 'buy-in' to rapid curriculum renewal, which could be assisted by their exposure to such things as completing a survey, and peer reviewing materials. These comments reinforced my rationale for the methodology which involves extensive peer review and hopefully subsequently 'buy-in' and ownership of the concept of rapid curriculum renewal.

5.2.3 IJSHE Journal Reviews

In September 2008, I submitted the revised six papers which I had lead-authored, for double-blind peer review by the *International Journal of Sustainability in Higher Education*. The following paragraphs summarise the reviewer comments relating to content (formatting comments have been removed), and the way in which these comments were subsequently addressed.

Paper 1:

Reviewer 1: *'This paper is well written … Some statements need to be backed up by the literature'*. I reviewed the text with regard to statements that could benefit from additional referencing and made a number of minor amendments principally involving the addition of more references to support the statements.

Reviewer 2: *'The paper makes overall a good reading. However, it is not concise and is very descriptive at times ... There are some needs for improvements and an annotated copy is provided'.* I reviewed the text with regard to concise writing, and made improvements responding to the suggested minor amendments provided in the annotated paper.

Paper 2:

Reviewer 1: *'This is a good paper. At times it is a little long-winded but makes a good point. I would like to have seen a more graphical and less descriptive text, but it is overall ok'.* I made minor amendments to the text reviewed for improvements in language and concise explanations.

Reviewer 2: *'This is an interesting paper but it needs a greater degree of clarity as to what the main message is. Time is certainly an important aspects but quality is probably more important. Also, the role of some 'natural' catalysts such as the ability to attract and upkeep students – who ultimately ensure the survival of any course - needs to be considered'.* I added to the paper to clarify that quality is also an important factor in rapid curriculum renewal and added more references regarding the role of drivers (catalysts) in providing pressures to undertake EESD. I also added text to clarify that departments need to strategically plan curriculum renewal to ensure that they are not too far in front of student or industry demand (i.e. so that program viability is preserved).

Paper 3:

Reviewer 1: *'The papers offer a good theoretical basis, but the nature of the arguments are not supported by information from the real world … This means that curriculum renewal needs to be considered against a background of overloaded time-tables and tight schedules, as well as the limited resources available to pursue the changes outlined in the paper. If this would be to take serious, empirical information would be needed'*. I added text to clarify that the proposed strategies are based on the authors' own experiences and those of active colleagues in the field – projects are currently underway to test and refine these elements of curriculum renewal. Text was added to acknowledge that the curricula of undergraduate engineering programs may be completed within four years, although students can take longer, which needs to be considered in the curriculum renewal strategy with respect to the issue of broken programs and tailoring program requirements for students in the transition. The text acknowledges key barriers to curriculum renewal including overloaded time-tables etc. Additional text was added to clarify that curriculum renewal will be undertaken within this context of perceived barriers, and that part of a Department's role is to reduce these barriers and improve the benefits of curriculum renewal. I added several additional references to increase real world examples.

Reviewer 2: *'The subject issue of the paper is indeed relevant. It is however astonishing that the author failed to cite Murdoch´s graduate mapping. It is unfortunately not described in details on the paper despite the fact it is a well established web-based mapping tool that has been developed at Murdoch´s Teaching and Learning Centre (TLC) to facilitate the task of mapping graduate attributes to units. The SOLO Taxonomy was also not mentioned'.* There are a number of institutions undertaking graduate mapping exercises in Australia as noted within the Murdoch literature on graduate attribute mapping (in particular Griffith and the University of South Australia) and I chose in the writing to focus on tools that are readily accessible to the reader. However, I added reference to Murdoch's graduate attribute mapping initiative and tool, noting that a mapping tool has been developed, but is restricted to Murdoch staff (only a couple of papers could be found which document the Murdoch experience, in computer-IT literature). I also included a reference to the SOLO taxonomy as literature context to the mapping process, and an example to show how the SOLO taxonomy relates to the development of competencies and graduate attributes through progressively more complex course learning outcomes.

Paper 4:

Reviewer 1: *'The paper makes a good case for curriculum audit, but largely overlooks the fact that students are required to complete general engineering courses on topics such as mechanics, thermodynamics, electrical and engineering circuits, transport phenomena, and computer science. Little emphasis is given to sustainable issues per se although much could be gained by doing so'*. I clarified in the text that all engineering courses including general engineering courses and discipline specific courses require sustainability content to be embedded. The text highlights in a number of places that while little emphasis is currently given to sustainable issues per se in these courses, much could be gained by doing so, and also presents the argument that actually much could be lost by not doing so.

Reviewer 2: *'An article of this nature has an appeal and I was especially looking for the case studies but they are of curriculum assessment and not of a proper auditing. This is disappointing. The example by Monash is very useful but I am not sure the issue of resources was sufficiently analysed. Auditings have implications in both time and resources so that more convincing arguments to pursue them are needed if these are to become more widespread'.* I clarified at the commencement of the paper that an 'audit' is an evaluation of a system or process, to determine the validity and reliability of information, and to assess a system's internal performance against a set of predetermined criteria (i.e. graduate attributes). I also noted that due to practical constraints, an audit seeks to provide only reasonable assurance that the graduate attribute statements are appropriate, using a sampling approach to reviewing the program. The text now includes more text at the start of the paper, acknowledging the implications for resourcing. Depending on such constraints the audit may differ the consideration of some or all course outlines, lecture material and assessment briefs, interviews with the program convenor and some or all of the course convenors.

Paper 5:

Reviewer 1: *'The manuscript is very comprehensive and useful. It describes some important features of the links sustainability-curriculum and provides some useful examples of what is being done. It would be useful to summarise on table the various developments and their main features so as to allow a comparison'.* I created a table on course development and renewal options showing the advantages and disadvantages of each option, at the beginning of the section.

Reviewer 2: *'The paper reads well but between the lines one can feel a sense of self-assurance that this is the only way forward. There can be no model for including*

sustainability in the curriculum as there is, for example, for health and safety or regulations. Much depends on the degree of commitment from a given university. It could be useful to outline this aspect'. I added text to note that while the authors do not propose a one-model approach to embedding sustainability into engineering education, there are certainly common elements emerging in the literature and in the authors' and colleagues' experiences, which are shared within this paper. Text was also added to comment on the reality that university commitment can help to accelerate curriculum renewal progress through the provision of support such as funding, marketing and flexibility in rules regarding developing new courses and modifying existing courses. I also clarified at the commencement of the text that the options presented do not presume that this is the only way forward.

Paper 6:

Reviewer 1: *'The paper offers an interesting overview, but it is rather limited on its scope. Also, energy efficiency could not possibly be representative of ESD in engineering, being one example at most. The various deficiencies seen in the survey work makes it unlikely one may use this as a basis for other surveys as the article suggests'.* The title was subsequently reworded and the introductory text modified to acknowledge and explain the limitations in scope, noting some possible reasons for the lack of research on the state of EESD (complexity, funding and concern about the implication of results). The rationale for the survey was then explained in the paper, highlighting that energy efficiency is not considered to be a potential replacement indicator for examining the state of ESD in engineering, it is shared as an example of how information about EESD can be obtained, addressing the survey constraints identified with regard to funding and complexity. More detail was also provided on the methodology.

Reviewer 2: *'The paper promises but does not deliver. The general words on worldwide trends do not match the need for a detailed overview of SD in engineering worldwide as the title implies ... The conclusions section does not offer any outline of future prospects'*. I refined the title of the paper to address the comments provided by the reviewer. In particular the text now clarifies that unfortunately, although there is a need for a detailed overview of sustainability content in engineering worldwide, this has not yet been undertaken. Additional text has been added to make sure the reader is clear as to why there are only general words on worldwide trends. Within the survey section, text has been added to highlight the rationale, choice of methods, sample characteristics – the full explanation of which is contained within a report on the survey. There are no graphics (rather descriptive text) as the survey data was not quantitatively

analysed in detail using statistics software, due to the indicative (rather than comprehensive) nature of the data collected (this is clarified in the methodology). The conclusions section has been amended to better highlight the key points of the paper and to highlight opportunities for future prospects.

5.2.4 Further publication intentions

In 2008, subsequent to the journal peer-review process, in liaison with the journal editor it was jointly decided to proceed with a book publication rather than a special issue journal publication due to the constraints with word count and layout restrictions with tables and figures. Together with the journal editor, Mr Hargroves and I approached Earthscan who subsequently agreed to publish the manuscript, called *Engineering Education and Sustainable Development - A Guide for Rapid Curriculum Renewal,* with a 2010 publication date. I have received forewords for this publication from Mr. Barry Grear AO (President, World Federation of Engineering Organizations), Professor Goolam Mohamedbhai (Secretary General, Association of African Universities, and former President of the International Association of Universities), Dr Tony Marjoram (Head of Engineering Sciences, Division of Basic and Engineering Sciences Natural Sciences Sector, UNESCO), and Professor Walter Leal-Filho (Editor, *International Journal of Sustainability in Higher Education*).

5.3 Conclusion

In conclusion, each of the four stages of peer-review included an account of the evolution of thought about the problem, changes made to the elements, and additional questions that needed to be addressed to better understand the issues and opportunities facing engineering curriculum in seeking to rapidly embed sustainability knowledge and skills. The peer review process highlighted a number of further considerations for the model and component elements, which in addition to minor language issues, comprise the following:

- *The elements identified in the literature did not include the role of campus integration:* This element was subsequently added to the list of elements and the literature review process was revisited to include this topic area.
- *The description of the elements was largely a top-down and linear approach to curriculum renewal:* The text was subsequently included to clarify that the pressures for rapid curriculum renewal range from top-down, bottom-up to middle-out. Moreover, it was concluded that any model for rapid curriculum renewal would need to fit within any organisational structure if it is to be widely useful, with some or all of the elements being used in any order, depending on the organisational context. The literature review was also revisited to consider how the elements may be portrayed as non-linear and integrated in the form of a diagram, rather than just a table.
- *The research included few non-anglo references with regard to experiences of rapid curriculum renewal:* Further research was subsequently undertaken to check whether a body of work from non-English speaking countries had been missed during the initial literature review. It was subsequently concluded that this was not the case, but several additional references were included from Asia and South America to expand the literature base.
- *The research did not address the importance of quality teaching as a pre-requisite of rapid curriculum renewal:* Further explanatory text was subsequently included within the description of the elements and model, to acknowledge this reality. Moreover, it was concluded that the model needed to be explicit about its flexibility for use in a wide variety of pedagogical approaches, for example from didactic teaching through to problem based learning.

These findings were used to inform the elements and the development of the model, as presented in Chapter 6.

References

[1] Desha, C. and Hargroves, K. (2007) 'Elements of Curriculum Renewal to Embed Sustainability into Engineering Education', flyer, handouts and notes from the facilitated workshop, 2007 International Conference on Engineering Education and Research (iCEER 2007), 7 December 2007, Melbourne, Australia.

[2] Paten, C., Hargroves, K., Smith, M. and Stasinopoulos, P. (2007) 'The Importance of Sustainability in Engineering Education: A Toolkit of Information and Teaching material', proceedings of the IDC Engineering Training & Learning Conference, Brisbane, 12-13 September 2007.

[3] Desha, C. and Hargroves, K. (2007) 'Education for Sustainable Development Curriculum Audit (E4SD Audit): a curriculum diagnostic tool for quantifying requirements to embed sustainable development into higher education – demonstrated through a focus on engineering education', *World Transactions on Engineering and Technology Education*, vol 6, Issue 2.

[4] Desha, C. (unpublished) Audio recording and typed workshop notes from the facilitated workshop, 2007 International Conference on Engineering Education and Research (iCEER 2007), 7 December 2007, Melbourne, Australia.

[5] Desha, C. and Hargroves, K. (2007) 'Emerging Engineering Education Curriculum for Sustainable Development', flyer, handouts and notes from the facilitated workshop, 2007 Australian Association of Engineering Education Conference (A2E2 2007), 12 December 2007, Melbourne, Australia.

[6] Paten, C., Hargroves, K., Smith, M. and Stasinopoulos, P. (2007) 'The Importance of Sustainability in Engineering Education: A Toolkit of Information and Teaching material', proceedings of the IDC Engineering Training & Learning Conference, Brisbane, 12-13 September 2007.

[7] Davis, G., Desha, C. and Hargroves, K. (2007) 'Engineering Education for Sustainable Development: A Snapshot of global transitions, with a focus on the UK and Australia', proceedings of the Griffith University School of Engineering Faculty Research Conference, 'GSERC', Logan, Brisbane, 7 December 2007.

[8] Desha, C., and Hargroves, K. (2007) 'Education for Sustainable Development: Elements of Rapid Curriculum Renewal in Engineering', proceedings of the Griffith University School of Engineering Faculty Research Conference, 'GSERC', Logan, Brisbane, 7 December 2007.

[9] Desha, C., Hargroves, K. and Smith, M. (2009) 'Addressing the Time Lag Dilemma in Curriculum Renewal towards Engineering Education for Sustainable Development', *International Journal of Sustainability in Higher Education*, vol 10, Issue 2.

[10] Desha, C., and Hargroves, K. (In press) 'Sustainable Development and Engineering Education', 'Environmental engineering' and 'The State of Engineering for Sustainable Development', Marjoram, T. (Ed) Sustainable Development and Engineering Education, UNESCO.

[11] Desha, C. and Hargroves, K. (2007) 'Education for Sustainable Development Curriculum Audit (E4SD Audit): a curriculum diagnostic tool for quantifying requirements to embed sustainable development into higher education – demonstrated through a focus on engineering education', *World Transactions on Engineering and Technology Education*, vol 6, Issue 2.

[12] Paten (Desha), C., Palousis, N., Hargroves, C. and Smith, M. (2005) 'Engineering Sustainable Solutions Program - Critical Literacies for Engineers Portfolio: Putting Sustainability as a "Critical Literacy" into Mainstream Engineering Curriculum', *International Journal of Sustainability in Higher Education*, vol 6, Issue 3, pp265-277.

[13] Paten, C., Hargroves, K., Smith, M. and Stasinopoulos, P. (2007) 'The Importance of Sustainability in Engineering Education: A Toolkit of Information and Teaching material', proceedings of the IDC Engineering Training & Learning Conference, Brisbane, 12-13 September 2007.

[14] Desha, C. and Hargroves, K. (2009) 'Surveying the State of Higher Education in Energy Efficiency, in Australian Engineering Curriculum', *International Journal of Cleaner Production*, Elsevier, doi:10.1016/j.jclepro.2009.07.004.

[15] Desha, C. and Hargroves, K. (2008) 'Mainstreaming EESD: Elements of Rapid Curriculum Renewal - An Overview of the March 2009 Special Issue of the International Journal of Sustainability in Higher Education', proceedings of the 2008 Engineering Education for Sustainable Development conference, Graz, Austria, 25-26 September 2008.

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6. A MODEL FOR RAPID CURRICULUM RENEWAL

As discussed in previous chapters, society is increasingly calling for professionals across government, industry, business and civil society to problem-solve issues related to climate change and reducing environmental pressures. With the world moving towards a greener economy, professionals are needed who can deal with immediate and critical issues, in addition to professionals who can deal with longer-term chronic issues and future crises. This requires a dual track approach to rapid capacity building, in both postgraduate and undergraduate education.

In this chapter, qualitative findings from the literature reviews (Chapter 1 and 3), reflexive inquiry (Chapter 4), and peer review (Chapter 5) are synthesised into a model for rapid curriculum renewal to address this need. The chapter begins with a description of the model and its key conceptual areas. This is followed by a discussion of what might be expected as the model is implemented, considering each of the six identified elements that can promote rapid curriculum renewal.

6.1 A description of the model

Drawing on the qualitative findings of the previous chapters, a model for rapid curriculum renewal needs to portray the six elements of curriculum renewal and their integrated nature. Furthermore, it needs to highlight the reliance of the process on the setting of timeframes, institutional leadership, and strategic staging. It also needs to demonstrate the periodic yet highly organic nature of the process. In Chapter 4 (Figure 4-1), a ‘Sustainability Helix’, was identified as a flexible model which allows organisations to address periods of intense change. Such a directional but integrated model provides a sense of autonomy necessary for change within organisational settings. It also highlights the complex and non-linear nature of change, where stages and milestones allow for sometimes random and sometimes fully planned interactions. Applying these aspects of the model to the findings of the preceding chapters and substituting the organisational change elements for curriculum renewal elements, a model for rapid curriculum renewal is presented in Figure 6-1, and summarised in the following paragraph, with key terms underscored.

This is a period of rapid curriculum renewal within a continuous process of curriculum renewal. Entering the model from the left, the presence of one or more timeframe catalysts is required to set the period of rapid curriculum renewal, pushing the process forward as depicted by the two right-facing arrows. In the case of engineering education for sustainable development, key timeframe catalysts comprise program

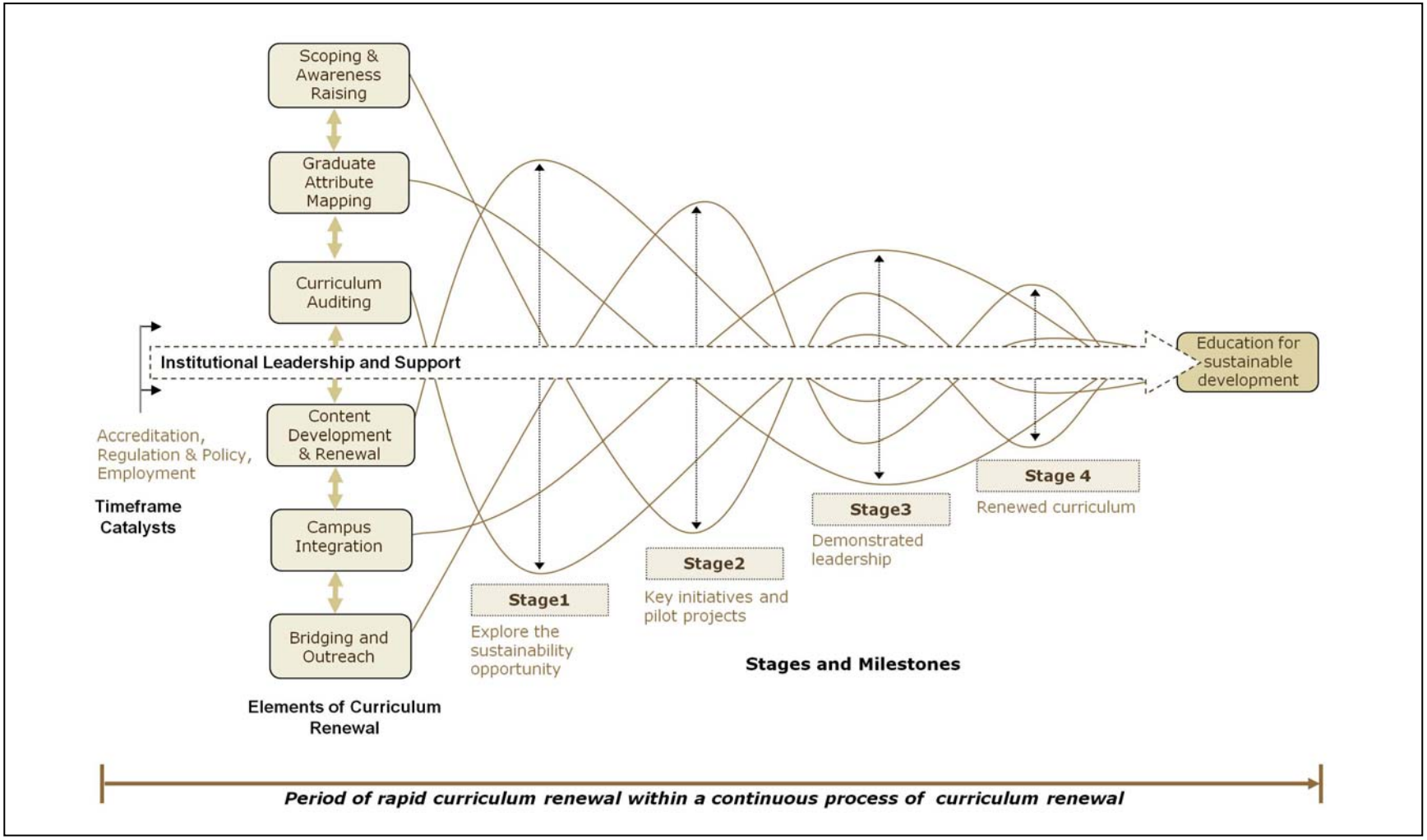

Figure 6-1. Stylistic representation of a model for rapid curriculum renewal

Source: Adapted from the *Sustainability Helix*, The Natural Edge Project (2005)[1]

accreditation, regulation and policy, and employment. Moving along the long arrow in the centre of the figure, institutional leadership and support is crucial to enabling the timeframes to be set within the institution, and to ensuring that a process of rapid curriculum renewal is maintained over the set period, ending with a curriculum that has embedded substantial new content. As shown by the boxes and vertical arrows on the left of the figure, six inter-related elements of curriculum renewal need to be incorporated into the rapid curriculum renewal process. The oscillating lines coming from each of the boxes highlight how the elements are considered and progressed in a dynamic manner. As shown by the boxes and double-headed vertical arrows along the bottom of the long arrow, a series of stages and milestones are required, which provide strategic direction to achieve a renewed curriculum in a time-constrained period. These conceptual areas are explained further in the following paragraphs.

6.1.1 Timeframe catalysts

It is clear from the literature that within the higher education sector, change is largely incremental until there are time imperatives – with clear time constraints – to undertake rapid curriculum renewal. As noted in the model, in the case of engineering education for sustainable development (EESD), catalysts that can set such timeframes include program accreditation, regulation and policy, and employment.

6.1.1.1 Program accreditation

Within regulated disciplines such as engineering, accreditation is a strong driver of change, setting a review period of 3-5 years for universities to continually reflect on and demonstrate how they have addressed existing and emerging accreditation requirements in their program/s, in order for their programs to remain endorsed by the accrediting institution. However in Chapter 1, accreditation was noted as quite a weak driver for EESD in reality, due to the lack of clear direction on how much or within what timeframe to embed sustainability into engineering curriculum.

Researchers Davis and Savage note that there is still plenty of room for improvement for accreditation to catalyse change within curriculum, as the interactions between universities and professional bodies are complex.[2] Indeed, regulation and program accreditation are influenced by a range of factors including industry requirements, student demands, government policy, the regulatory environment, and globalisation. A 2008 Review of Australian Higher Education by the Australian Deans of Built Environment and Design (ADBED)[3] concluded that accreditation focuses on compliance rather than innovation, where graduate outcomes desired by accreditation

panels are those most needed for 'work-ready' graduates, who cater to current employer needs, rather than looking ahead to future expectations. The report states:

> *'For universities to maintain their role in the formation of leaders for the emerging Australia, its economies and businesses, the accreditation processes need to maintain a focus on innovation and leadership rather than "training for work"'.*[4]

This lack of leadership in forward planning is exacerbated by the reality that accreditation agencies and their academic representatives on accreditation committees and boards do not necessarily have a good understanding of future needs and expectations for curriculum, resulting in a lack of ability to change accreditation requirements. This situation was highlighted more than a decade ago by the Australian Higher Education Council in their report on *Professional Education and Credentialism,*[5] which outlined difficulties when defining pathways for professional education.

6.1.1.2 Regulation and policy

Chapter 1 highlighted the role of government – at a federal, state and local level - to catalyse rapid curriculum renewal through providing both penalties and incentives. This could be for example through:

- *Regulation:* requiring industry to accelerate efforts such as energy efficiency assessments, which provides a signal to professional associations, accreditation bodies and the higher education sector regarding the timing for producing graduates with such attributes. Government roles include influencing professional accreditation requirements, using existing mechanisms such as the Australian Universities and Quality Assurance (AUQA) to work with accreditation bodies and organisations to provide the necessary 'calls for action' in priority knowledge and skills areas, to review and revise the coverage of accreditation requirements.
- *Research policy:* Government changes to selection criteria for research funding (such as Australian Research Council and Australian Learning and Teaching Council grants) including a sustainability-oriented research priority. This is particularly important given that early integration of emerging content appears to be driven largely by individual interests and research pursuits of the lecturers involved rather than formal strategic integration.
- *Teaching policy:* Government linking a portion of federal funding for higher education institutions to institutional learning and teaching performance with regard to integrating sustainability knowledge and skills into curricula (i.e. in a similar

manner to the way in which institutions currently track integration of other priority areas such as indigenous knowledge, and research-led teaching).

An example of such a catalyst can be seen in the example of the federal government's 'Energy Efficiency Opportunities' program, launched in July 2006, which required more than 220 businesses (representing around 45 percent of national energy demand) that use more than 0.5 PJ (139,000 MWh) of energy per year, to undertake an energy efficiency assessment and report publically on opportunities with a payback period of up to 4 years.[6] Further to this, Victoria was the first state to require all EPA license holders using more than 0.1 PJ (27,800 MWh) to implement opportunities with a payback period of up to 3 years, through its 'Industry Greenhouse Program'.[7] As a result of implementing these programs, both state and federal government has identified a significant skills shortage in the area of undertaking energy efficiency assessments.

Subsequently the federal government initiated a 'Long Term Training Strategy for the Development of Energy Efficiency Assessment Skills', beginning in 2009 with an extensive survey process across the energy intensive industries, energy service providers, and universities.[8] In 2007, the CSIRO (Commonwealth Scientific and Industrial Research Organisation) through its 'Energy Transformed Flagship' engaged in providing capacity building notes for professionals and students looking to up-skill in this area, funding a 30-lecture series (freely available online) aimed at both undergraduate education and professional development, on energy efficiency opportunities.[9] Australia's peak engineering professional body, the Institution of Engineers Australia, has also acknowledged that, '*The need to make changes in the way energy is used and supplied throughout the world represents the greatest challenge to engineers in moving toward sustainability'.*[10]

6.1.1.3 Employment

As discussed in Chapter 1, both government and industry are significant potential catalysts in their role as current and future employers of postgraduate and undergraduate students, setting clear expectations about changing future employment and training needs. For example:

– *Employer demand:* Both government and industry could assist professional organisations and universities (for example through advisory boards) to identify current and future industry demands for graduates with specific knowledge and skill capabilities, and the demands of future undergraduate and postgraduate students.

– *Employee professional development:* Government and industry could require employees who are undertaking professional development, to include time each year dedicated to learning about sustainability related technology and innovations.

6.1.2 Institutional leadership and support

Although change management is not the focus of this thesis, it is clear from the preceding chapters that departmental leadership needs to be present to action the timeframes set by catalysts such as accreditation, regulation and policy, and employment. As depicted by the long arrow in the centre of the model, this conceptual area is tightly associated with the timeframe catalysts, and is necessary throughout the rapid curriculum renewal process. According to an American campus sustainability assessment project, HEIs which are leading in embedding sustainable development knowledge and skills within the curriculum share a number of characteristics:

> *'First, these 'sustainability leaders' have adopted serious strategies for systematically addressing the sustainability of the institution ... Second, these institutions have provided the resources needed to implement their sustainability plans … Third, these sustainability leaders know where they have been, where they are, and where they are headed in terms of sustainability'.*[11]

This conclusion is supported within engineering education by a 2008 report to the Australian Teaching and Learning Council (formerly the Carrick Institute) on addressing the supply and quality of engineering graduates for the new century, which observed four supporting actions that were common in institutions facilitating significant change, namely vision, leadership, stakeholder engagement, and resources.[12] Hence, it is clear that management will need to consider a range of incentive mechanisms to gain and maintain such leadership and momentum throughout the rapid curriculum renewal process. Considerations synthesised from the literature are listed in Table 6-1.

Table 6-1. Leadership considerations in supporting rapid curriculum renewal

Leadership Action	Description
Strong commitment to action	Making a strong commitment from department executive level to the process, including communicating the intent of the activities to reduce staff anxiety about the process.
Internal champion	Securing an internal 'champion' responsible for leading the rapid curriculum renewal process (e.g. to gain executive level commitment and the development of the subsequent plan of action).
Formal requirement for involvement	Including a formal request for staff to participate in the rapid curriculum renewal process, with a clear statement of the timelines and expectations.
Recognition of	Recognising staff who have already embraced EESD and encouraging

Leadership Action	Description
strengths	them to share their curriculum renewal experiences with other staff (e.g. service award, invitation to present, invitation to sit on boards and committees related to EESD).
Flexible workload allocations	Providing research assistance, teaching buy-out, or flexibility in staff appointments (e.g. research/teaching/service proportions) for staff to actively contribute to the EESD curriculum renewal process.
Seed funding provisions	Providing seed funding opportunities (e.g. internal grants) for staff to investigate research opportunities in this area.
Flexible curriculum development	Permitting and encouraging staff to appropriately use existing academically rigorous and cutting edge course materials available online under open-source common attributes licensing arrangements.
Support for professional development	Providing opportunities and financial resources for professional development in the new area, regarding this as a portfolio strengthening activity. This could be linked to specific requirements (e.g. becoming familiar with the topic area, identifying aspects that can be immediately incorporated into existing curriculum, identifying material in demand for post graduate and professional development courses, or attracting regional/ international students faced with sustainable development challenges).

6.1.3 Elements that promote rapid curriculum renewal

As identified in the preceding chapters, six elements of curriculum renewal are essential to engage institutions and staff in a time-constrained process of rapid curriculum renewal. These elements are summarised in Table 6-2. The model uses vertical double-headed arrows between each of the elements, and oscillating lines along the curriculum renewal process, to show how they interweave with each other as rapid curriculum renewal unfolds. Such interactions may be in parallel or linear, synchronous or asynchronous, with different emphases at different stages in the process, depending on each institution's strategic plan for implementation.

Given the focus of this thesis investigation in distilling and understanding these elements, this conceptual area is used to explore implementation considerations in the following section, from the perspective of each element and its component mechanisms that could contribute to accelerating curriculum renewal towards EESD.

Table 6-2. Summary of six elements that are essential in rapid curriculum renewal

Element	Summary
Awareness raising and developing a common understanding	– Bringing staff (academic staff) to a common understanding of challenges, opportunities and implications for curriculum renewal at the department level through activities such as keynote lectures, public addresses, lunchtime seminars, media articles, and profiling existing sustainability initiatives. – Senior management in the department identifying what capacity is available to deliver sustainability content within the program offerings.
Graduate attribute mapping	– Facilitating scoping workshops with staff and other collaborators within the university hierarchy, to focus on the 'Graduate Attribute' requirements for graduating students and how sustainability knowledge and skills relate to these requirements. – Rethinking the relevance of curriculum content to deliver graduate attributes and skills, rather than 'starting from scratch'.
Curriculum auditing	– Providing a strategic (risk management) opportunity to review the extent of sustainability content within courses, which then assists in identifying areas of focus for the introduction and consolidation of sustainable development content across a given program. – Applying a risk management approach to the timing and prioritisation of the curriculum renewal process, while acknowledging efforts already undertaken in curriculum renewal for sustainable development.
Content development and renewal	– Planning the curriculum development and renewal over the desired timeframe for full integration. – Considering the merits of possible strategies such as 'niche programs', 'flagship courses', and institutional considerations like the availability of existing content and management support.
Bridging and outreach	– Extending the utility of course development and renewal to improve recruitment from industry and government, high schools and the community. – Considering opportunities for existing courses to be offered in an intensive format to industry and government as professional development (i.e. bridging), or to high-school students and the local community (i.e. 'outreach').
Campus integration	– Enhancing the course development and renewal process by linking theory about education for sustainable development curriculum with on-campus application opportunities. – Providing staff with practical experience in their subject matter and providing students with real project experience.

6.1.4 Strategic staging

It is clear from the preceding chapters that periods of rapid curriculum renewal fit within a continuous process of curriculum renewal underway in higher education institutions (see Figure 1.4, and Chapter 3). Furthermore, curriculum renewal requires an overarching plan, which should result in a process that preserves institutional diversity and innovation. As noted in Figure 6-1 by the stage boxes, this transition includes tasks that are defined with clear staging and an endpoint whereby the curriculum may be said to have achieved 'education for sustainable development'.

Drawing on the staging considerations organisational Sustainability Helix (Chapter 4), this model includes four stages of rapid curriculum renewal, whereby:

- In Stage 1 of the model, the institution considers options to determine what value 'EESD' could bring to its mission and business model.
- In Stage 2 the institution tests the business case for EESD through key initiatives and pilot projects.
- In Stage 3 the institution has made a systemic commitment to EESD through its operation and influence. The institution builds upon its responsibility by taking a public leadership role within industry, the local community, and the world at large.
- In Stage 4 the institution completes the embedding of EESD within the curriculum, producing its first graduates who can contribute to genuine progress in economic and social development, in the local community and the world at large.

Within this context and drawing on the findings from Chapter 3 regarding curriculum renewal processes, the challenge is to compress the timeframe for the three phases of curriculum renewal (i.e. ad hoc, flagship and integration) through strategic staging and milestones, to ensure that the outcome is rapid (i.e. 2 accreditation cycles, or 6-8 years) rather than standard curriculum renewal which can span up to 4 accreditation cycles (i.e. two decades).

As highlighted by the interwoven strands, there are variations in what may occur along the way, depending on the organisational context and existing frameworks. Hence, the composition of each stage is not fixed. In addition, departmental activities may change and develop to include new ideas and emerging knowledge and skills.

6.2 Implementation considerations by element

Given the focus of this dissertation on distilling the curriculum renewal elements that promote rapid curriculum renewal, this section uses the findings of the preceding chapters to discuss how such a process might proceed. Each of the elements are considered in turn with regard to staging and milestones, and potential barriers and benefits to planning and implementation.

6.2.1 Raising awareness and developing a common understanding

This element comprises the preparatory role of awareness raising activities among staff, with regard to changing professional roles, emerging knowledge and skill requirements, and implications for curriculum renewal in their department. If key staff are not familiar with what EESD means, then awareness raising and capacity building would be important precursors to curriculum renewal meetings or workshops.

Commonly, within the first six months of Stage 1, there are activities related to raising awareness and developing a common understanding of the issues. This is followed by continuing professional development to support the process. In addition to ensuring that staff have a strong base understanding of EESD and this knowledge is updated as required, this element can also be used to ensure communication between the six elements so that staff are kept updated as to progress. This may enhance the potential for capturing synergies across the elements and further strengthen efforts and understanding of staff.

Awareness raising may be undertaken through activities such as an address from senior management, keynote lectures by leaders in the field, documentaries or current affairs coverage, the distribution of journal and media articles, and profiling existing sustainability related initiatives and/or champions within the university community (i.e. ‘top-down’ approach). Such activities may also be initiated by staff and students, through informal or formal groups and associations within the higher education institution, the discipline’s professional body, or other special interest groups (i.e. a ‘bottom-up’ approach). Departments may also choose a ‘middle-out approach’ employing a staff member at a senior level (i.e. Director) with sustainability expertise to demonstrate commitment and who can also raise awareness with staff and the community in the form of internal and external press releases, interaction with colleagues and seminars. Depending on the culture of the institution, interaction may also include obtaining ‘buy-in’, by asking staff to vote through a ‘referendum’ on whether they think it is something the department should proceed with.

While the process will depend on many institution-specific factors, there are a number of common misconceptions alluded to in EESD literature, which could affect the progress of curriculum renewal initiatives unless senior management proactively addresses them. Key misconceptions are highlighted here as statements (italics), followed by suggestions for how they may be addressed:

1. *Embedding sustainability content is risky:* Embedding sustainability knowledge and skills into engineering education is not a new concept. Staff are not trying something 'risky' or new, and they are not at the 'leading edge' in doing so. Rather, it is now a requirement in many accreditation systems, for engineering education to include at least some sustainability knowledge and skills. As detailed in earlier chapters, if engineering institutions do not keep up with changing expectations in the profession, industry, government and the community, then they are likely to fall to the bottom of the list of preferred destinations of study and research.
2. *Students should just be given the fundamentals which they then apply throughout their career to problems and challenges:* Some staff don't want to reduce fundamentals education to include another hot topic. However, EESD is not a passing agenda and it is about integrating with, rather than removing these fundamentals or reducing their importance within curriculum. EESD is about fully integrating sustainability knowledge and skills within the pedagogy of every course within a program of study as an appropriate process to develop graduate attributes.
3. *Programs already have a full quota of content that is all critical to learning:* By the very nature of curriculum design, courses will always be 'full', however course content changes over time in response to changing student needs and staff interest and expertise. For example, engineering skills and knowledge that did not exist as little as 5 to 10 years ago, particularly in the information technology and communications areas are now regarded as essential. Required knowledge and skills to address issues such as climate change and sustainable development need to be incorporated into much of engineering education - from foundation courses that underpin all discipline studies, to courses that are highly discipline specific.[13]
4. *The old program needs to be discarded:* Making a transition to EESD does not require 'starting from scratch', rather it will likely result in some changes within almost every course. Instead of immediately discarding the content from existing courses, curriculum renewal requirements need to be identified through a systematic process of considering the knowledge and skills needed within the context of the existing strengths and niche qualities of the programs on offer.

As awareness raising activities proceed with staff, senior management needs to understand the department's capacity to deliver sustainability content within the program offerings. The term 'developing a common understanding' does not mean that everyone has to agree, or conformity needs to be achieved. Rather, senior management needs to be aware of how EESD affects the department, and the department's perspective. Incorporating this element into the curriculum renewal process can facilitate discussion to proceed with less argument, as explained by Fisher and Ury in their negotiation handbook *Getting to Yes*.[14] Mechanisms for considering current and potential capacity within the department, and budget implications and possibilities include:

5. *Clarifying the competition:* Before investing time and resources into this potentially significant endeavour of curriculum renewal the department could undertake a 'reconnaissance' to answer questions such as: *What graduate employment opportunities are there in the field? What is the existing student interest, at a masters and undergraduate level? What professional institutional accreditation requirements are there, to embed this new content within our offered programs? Are there signs that they will become more stringent? Is there a current or impending shift in legislation that will affect the programs on offer? What sort of media attention is being given to the field, our programs and our competitors? What is the competition doing (locally, elsewhere in this country, and internationally)?*
6. *Benchmarking the department:* There is also benefit in knowing where the department is located within this context, to understand how much work is required. Such benchmarking of the department might involve asking questions such as: *What is the existing level of interest among our staff? What are the achievements to-date in this field? What existing expertise is there among existing staff and elsewhere in the university, with respect to teachers and researchers? What is the department's appreciation of the current level of integration of education for sustainable development at a degree program level? What is happening with regard to education for sustainable development elsewhere in this institution? Is there senior executive level commitment? Does the academic plan, or any policy statement highlight education for sustainable development?*

The department may also want to ensure that decisions on 'how far' and 'how fast' the curriculum renewal process should proceed are in alignment with market expectations. An advisory panel may be useful for this review process, which could be an extension of the role of existing advisory panels for strategic direction and accreditation reviews.

6.2.2 Identifying and mapping graduate attributes

In order to decide on actions to be taken, the department needs to have a clear understanding about what new graduate attributes are desired (also referred to as 'learning outcomes', 'capabilities' and 'competencies' in the literature - see Chapter 3). This element highlights the strategic role that reviewing and mapping graduate attributes for a given program can play, in informing and streamlining curriculum renewal.

As with awareness raising, identifying and mapping graduate attributes are often focused on in the first stage to build a benchmark for performance related to EESD. Immediately following internal capacity building, senior staff need to become familiar with internal strengths, weaknesses and staff capacity; this might take up to six months by the time internal reporting is undertaken. Alongside this process, the process of graduate attribute mapping needs to occur within the first year, potentially between 6-12 months. Once identified, the list of preferred graduate attributes can then be revised periodically to reflect influences of various catalysts. This might include increasing EESD requirements as part of course accreditation, shifts in graduate expectations of employers, and changes in national legislation in the area.

Graduate attribute mapping can play an important foundation role in facilitating rapid curriculum renewal, as it quickly develops a shared understanding of a department's aims and aspirations for graduates, and the program's graduate market niche (regionally, nationally and internationally). The process also encourages reflection on how courses and programs can address accreditation requirements, and focuses attention on how preferred graduate attributes are already being developed through curriculum goals, learning objectives and assessment methods.

In the emergent stages of EESD, graduate attributes may be aimed at just meeting existing accreditation requirements, and ensuring that the graduate attributes that are required for accreditation are appropriately mapped across the courses might be the extent of the graduate mapping process. The resultant graduate attribute map can be an important tool to demonstrate how accreditation graduate attributes related to the new knowledge and skills will be developed during the program (i.e. to reduce *current* accreditation risk exposure by demonstrating compliance).

Alternatively, a department may aim to go beyond existing accreditation requirements, anticipating future regulatory, market and accreditation requirements and planning for the development of graduate attributes to meet these demands as they arise. In addition to 'accreditation graduate attributes', each department might consider a set of

'beyond compliance' graduate attributes that foresee emerging issues and particular accreditation requirements becoming more stringent in the future. For example, an accreditation graduate attribute might state that every graduate must have, *'an understanding of the environment'*. A 'beyond compliance' graduate attribute developed by the department might be that every graduate must have, *'an understanding of the limitations and thresholds of environmental systems'.* Another might be to have, *'the ability to calculate carbon emissions from the construction and operation of infrastructure'*.

In this way, a unique set of EESD related attributes evolves for each department, from a variety of inputs including university commitments, industry (market) signals, staff workshops, and student feedback. Furthermore, there might be different expectations within the department, depending on the strengths within the disciplines. Senior management may wish to ensure that the aspirations of staff members and stakeholders are reflected in this set of graduate attributes, as an important mechanism for keeping key staff, who might otherwise move to institutions who are achieving beyond compliance. The process for developing these graduate attributes may comprise one or more workshops or meetings where key staff members systematically focus on how sustainability knowledge and skills relate to these requirements (a process for doing this is presented below).

Once this set of graduate attributes has been generated, the department can then prioritise these attributes so that they can then be strategically integrated in the department's curriculum renewal process. Given budgetary and accreditation pressures facing departments, it is considered likely that priority will be given to anticipated shifts in accreditation requirements i.e. how likely each of these graduate attributes is to be assessed in the next round of accreditation, or included in future accreditation. This study refers to these as 'anticipated accreditation' graduate attributes, which indicates that the department is achieving 'accreditation compliance +'. For example, the department might consider that having *'an understanding of the limitations and thresholds of environmental systems'* is likely to become an accreditation requirement within 5 years.

Consideration might then be given to those remaining graduate attributes that the department sees as important to set the department ahead of competitors as an industry leader. This study refers to these as 'market leader' graduate attributes, which indicate leadership. For example, the department might consider that *'the ability to calculate carbon emissions from the construction and operation of infrastructure'* is a

highly marketable skill that, while not required for accreditation purposes, will differentiate the program from competing institutions offering similar programs.

The prioritisation process could be informed by directly approaching the accreditation body and seeking advice on future directions for accreditation, or by comparing the existing requirements with international 'best practice' accreditation requirements. The department can then use these prioritised 'anticipated accreditation' and 'market leader' graduate attributes together with the 'accreditation' graduate attributes, to produce an augmented graduate attribute map as shown in Table 6-3, which demonstrates how the selected graduate attributes will be developed throughout the program. The attributes could also be shown in stages, for example in two or more graduate attribute maps could be annotated with 'by 2010' and 'by 2015'. The resultant map/s can then form the basis for future monitoring and measuring of progress with regard to how well the graduate attributes are developed by program completion.

Table 6-3. Example of varying graduate attribute goals for undergraduate courses

Course Code	Course Name	Graduate Attributes								
		'Compliance' Existing Accreditation			'Compliance +' Anticipated Accreditation			'Leadership' Market Leader		
		Attribute 1	Attribute 2	Attribute 3	Anticip Att. 1	Anticip Att. 2	Anticip Att. 3	Additional Preferred Att. 1	Additional Preferred Att. 2	Additional Preferred Att. 3
1010	Introducing Engineering	M	-	L	-	-	-	M	L	-
1020	Engineering Structures	L	-	-	L	-	-	M	L	-
1030	Engineering Materials	L	-	-	M	M	-	L	-	-
1040	Thermodynamics	L	-	-	-	-	-	-	-	L
1050	Electrical Systems	L	-	-	-	-	-	-	-	L
1060	Engineering Computing	-	L	-	L	L	L	-	L	M

-	None	L	Little emphasis	M	Moderate emphasis	H	High (strong)

6.2.3 Curriculum auditing

Once there is general awareness about the need for new knowledge and skills in the curriculum, and key staff have reached an understanding about what new graduate attributes they would like their graduates to acquire, a key consideration is which areas of the program should be prioritised for action i.e. 'does the current curriculum sufficiently develop current sustainability related graduate attributes as defined by

accreditation?' and furthermore, 'does the curriculum develop additional sustainability related graduate attributes as defined by the department?'.

This could be addressed using an audit to define what specific expertise might be lacking in the department, for potential future appointments and/or collaboration. Alternatively the audit could proceed using a set of graduate attributes from other HEIs (for example competitors), or by using relevant program accreditation criteria. As each of these options about the audit criteria has implications for resourcing and time, the rigour of the subsequent audit and subsequently the credibility of results, the decision should be given careful consideration. Such a diagnostic process could be an important mechanism to reduce the potential for gaps in curriculum, resulting in potential accreditation issues, and new curriculum that does not necessarily meet the immediate needs of graduating students or future employers.

As with awareness raising and graduate attribute investigations, activities related to curriculum auditing are often focused on in the early stages (i.e. Stage 2 or 3) to provide a summary of the state of existing programs in relation to EESD. This may take up to six months, during which time awareness raising continues and senior management develop strategies for addressing staff knowledge and skills gaps and taking advantage of existing strengths. Following the development of the audit report the process can be repeated periodically for two main reasons. Firstly as the audit report will outline potential areas for improvement for a particular subject the progress in responding to these recommendations can be audited periodically, potentially based on a report from the course convenor. Secondly as graduate attributes are periodically revised the audit report for a particular course can be revised to identify potential new areas for improvement based on shifting preferred graduate attributes, such as from more stringent accreditation requirements.

Rather than putting the future of all courses within a program into question, the audit process works within the existing program structure, highlighting areas where sustainable development theory, knowledge and application can be better integrated, along with where 'old industry' content can be phased out appropriately. Degree programs need to cover fundamental theory and knowledge that are critical to the relevant disciplines (for example in engineering, the basics of statics, dynamics, materials etc). Furthermore, there is also the requirement for non-technical critical literacies, including professional skills and ethics. EESD is not about replacing course content but more about a strategic rethink of how the fundamental theory and knowledge relate to meeting society's needs in the future, as we now understand them.

An example process for conducting such an audit was published as a paper, based on personal experiences in the field.[15] In summary, the process includes a preliminary diagnosis and classification of each course within the program, with regard to graduate attribute development across (breadth) and within (depth) the program. The audit process requires the department to consider each course's performance against what the department has previously outlined for graduate attribute development in these courses (see Table 6-3). Following the example outlined for graduate attribute mapping, the audit would assess whether ENG1010 actually provides a 'moderate emphasis' on Attribute 1 and Additional Preferred Attribute 1, and a low emphasis on Attribute 3, and Additional Preferred Attribute 2. The audit outcome is then a categorisation of courses with respect to renewal needs to meet the intentions of the Graduate Attribute Map, from those requiring no further action to those requiring significant effort.

In this process, the intention for a curriculum audit is to assess overall how well specific sustainability related graduate attributes are developed within the current program. This includes identifying areas within the existing curriculum that omit or conflict with recognised sustainability principles, theory and application as agreed by the specific accrediting institution. It also includes identifying inconsistencies - both in the language and message of sustainable development theory, knowledge and application - across and within course offerings. The audit also highlights efforts already underway in curriculum renewal for sustainable development and identifies ways to build on these efforts. This part of the process is important in providing an open forum for staff to discuss their curriculum innovations with colleagues in the department, creating the opportunity for strategic and systemic discussion about how staff will proceed with EESD in a way that aligns with their tacit requirements for students.

Following the outcomes-based approach used by member countries of the International Engineering Alliance's *Washington Accord*'[16] the audit takes an 'outcomes-based approach' to evaluating curriculum, which is intended to preserve and encourage program diversity and innovation. Audit criteria would be developed for each discipline based on the agreed graduate attributes, covering the specific principles, questions and content areas that should be covered. As the tool is intended to encourage reflection and dialogue about curriculum which is likely to include substantial tacit knowledge on how content is being delivered in addition to standard curriculum documentation such as program and course outlines, assessment and lecture notes, it is important that it is used *by* staff in the department, *for* the department. While an audit process might be perceived as threatening for some staff, evaluating a program can

also be energising for staff, when they can see the opportunity for support to develop ideas that they have perhaps had for a while, and to renew their course content. Indeed, it may help to formalise previous *ad hoc* approaches to curriculum renewal as course convenors who see student demand and changing trends can report their observations to management through the collaborative nature of the audit. However, undertaking an assessment or audit of curriculum will not necessarily result in curriculum renewal unless supporting measures are put in place that facilitate review and implementation of the audit recommendations.

The results can then be used to consider what should be prioritised for curriculum renewal (and staff resourcing), to provide an immediate 'critical mass' of sustainability content that sufficiently develops the required graduate attributes for the program, and what can then be addressed in the medium to longer term with regard to strengthening this arrangement and developing other attributes. There is a significant opportunity for management to be flexible and innovative in guiding the curriculum renewal process, ensuring that program accreditation requirements are met, while supporting staff creativity, improving marketability of the program and ultimately providing staff with the opportunity to contribute positively to society's sustainable development challenges. There is also the opportunity to use this process for benchmarking to provide a common reference point for discussing progress and to assist in evaluating the impact of various initiatives. In summary, a non-confrontational and collaborative audit process can provide a systematic and risk management based approach to embedding sustainability within engineering curriculum while preserving the program's diversity and innovation.

6.2.4 Content development and renewal

Given the variety of factors affecting content development, there can clearly be no 'one-model' option for rapidly embedding sustainability into engineering curriculum. However, a department may consider the merits of several emerging curriculum renewal strategies in formulating its own strategy for curriculum renewal, suited to its institutional, geographic, financial, political, social and cultural context. This element highlights the need for strategically planning the curriculum renewal process, to create a transition that minimises disruption and effort, involving planning from the outset as to the best approach. The text begins by discussing the new 'sustainability degree' option and options for integrating sustainability content within existing degrees and programs, then discusses two popular approaches to curriculum renewal and their application to EESD: autonomous 'flagship' courses that promote EESD, and 'integrated' courses that address aspects of EESD.

In contrast to the previous three elements, activities related to content development and renewal are often focused on in the mid-stages (i.e. Stage 3 onwards) building on from knowledge gained from graduate attribute mapping and the curriculum audit of strengths and weaknesses in course materials. Ideally this will involve the use of a dual track approach for undergraduate and post-graduate curriculum renewal, to strategically address immediate and longer term capacity building, over a period of 18 months. It will also involve engaging with campus facilities management, to determine opportunities for integrating curriculum renewal with campus operations. As with the previous elements once the bulk of the recommendations from the audit process have been responded to there will be an ongoing need to refresh courses based on shifting external requirements or advances in the field.

6.2.4.1 Sustainability degrees or program

Niche degrees are specialisations existing either within a larger discipline context (for example *sustainable energy systems* within engineering), or as a 'hybrid' or 'transdisciplinary' knowledge area that cuts across traditional boundaries (for example *Environmental Management* involving Environmental Science, Engineering, Business and the Arts). When faced with the challenge to respond to current and future anticipated requirements for EESD, a department may consider creating a niche degree to cover the material rather than integrating the material into current programs.

Niche degrees and programs may be popular where there are clear career outcomes for graduates, as they can be marketed as a fast and focused pathway for students to acquire the definitive skills set. Such programs might be particularly attractive to departments if they can entice full fee-paying international students who cannot access such specialist training in their own country. The new course option may also be exciting and involve a core group of staff whereas integrating across programs calls for all staff to be involved to some degree and might be viewed by staff as intrusive and laborious.

However, there is a risk in this instance that if a new degree or program is developed in place of implementing changes to existing courses and programs in the core disciplines, EESD may be reduced to an elective area of study (for example just in the Environmental Engineering discipline, or in an environmental major), without developing EESD graduate attributes in the majority of engineering students as it applies to their discipline. Furthermore, there are at least three potential complications.

– Firstly, many aspects of sustainable development require taking a cross-disciplinary 'whole of system' approach, where the members of a given project or design team

are called to draw on their base grounding in a given field to apply to integrated challenges and to interact with each other to deliver an optimal systemic solution. With this in mind, niche bachelor (or indeed even postgraduate) degrees have the potential risk of being too broad in learning outcomes as opposed to a discipline based degree and may find it difficult to gain accreditation or endorsement from professional institutions. For this reason niche program entry requirements may need to include pre-requisite knowledge comprising a discipline-based degree or equivalent.

– Secondly, although there may be preliminary spikes in enrolment due to the novelty value of a 'sustainability degree', graduating students may struggle to find employment in areas other than those involving general sustainability concepts due to a lack of a specific disciplinary grounding. In contrast, students graduating with a well known and well regarded base degree that has had sustainability integrated throughout can both meet existing demands and expectations, while also offering a point of difference in their capabilities. This problem with niche degrees was highlighted more than a decade ago by the Australian Academy of Technical Societies and Engineering in a review of engineering education in Australia, where the authors concluded that:

'… it is imperative that environmental issues are integrated into single branch engineering courses, such as electrical engineering, civil engineering etc. Within these courses, environmental issues should be integrated into existing course modules, as well as being taught in specialised environmental subjects'.[17]

– Thirdly, developing a new niche degree requires recruiting students to a new program which has very little visibility in the market, rather than building on the recruitment profile and market visibility of existing programs. In contrast renewing existing programs allows such leveraging off existing enrolments and notoriety, and shows that the department's existing programs are attuned to recruitment market and employer market needs, i.e. 'moving with the times' rather than stagnating.

– So, while there may be strong inertia to create new niche degree offerings,[18] universities who can integrate sustainability content within their existing programs have an opportunity to attract more students to existing degree programs, as well as leveraging off market placement, branding and notoriety already in place. For example, international leaders in engineering education such as MIT, Delft, Carnegie, Tokyo University, and UPC-Spain are demonstrating through their programming, that integrating, or 'embedding', these materials across the spectrum

of university curriculum, combining integrated undergraduate bachelor degrees with postgraduate specialisations in sustainable development topics, is positioning them to be leading universities in the following decades;[19] the 'new world' ivy league.

6.2.4.2 Sustainability flagship courses

As with so many other military terms, 'flagship' has crossed over from military meaning into common vocabulary. The original meaning for a 'flagship' is the lead ship in a fleet of vessels used by the commanding officer, which is the largest, fastest, newest, or the most well known. It is used to quickly identify the fleet to others, and also to coordinate the fleets movements and activities. For these functions, the flagship needs to have fine-tuned communication requirements.[20] It now has common derivations such as the 'flagship project' of a government, a 'flagship product' of a manufacturing company or 'flagship store' of a retail chain.

Within higher education curriculum development, 'flagship courses' are used frequently within bachelor programs to highlight the institution's commitment to a particular field of knowledge like advanced computer modelling, or project management. Over time, departments might integrate this material into relevant parts of courses across the program to then make way for new flagship courses. Traditionally this process allowed new material on topics, such as ethics and safety, to be vetted by staff, students and alumni to allow demand for the content to be established. The flagship course might be placed anywhere in undergraduate or postgraduate programs, convened by the resident expert or 'champion' within the department. For example, at an introductory level, a common introductory course for first year students might be developed to 'kick-start' their learning in a certain topic area. At an intermediate or advanced level, flagship courses might be developed to cater for learning in a new content area previously not addressed in the program and offered as part of a minor or an elective.

The flagship course approach has a number of potential advantages. It can send a clear signal to staff, students and potential future students about the program aims and distinguishing features and its future direction. It can also raise awareness among staff in considering what the new content area means to their field of specialisation, particularly if they are asked to teach a module in the flagship course, or to convene the course. Flagship courses can also help the department manage the time lag between training in new content and the demand for graduates with this new knowledge and skill set, by gradually replacing existing courses with new 'leading edge' content, to cater for changing graduate skill requirements.

However, in adopting a flagship course approach, there are several potential pitfalls. If the topic or key message highlighted by the flagship course does not represent the rest of the degree program then there is a risk that students who have enrolled partly because of the flagship will become disillusioned with the program offering and potentially leave the program. Furthermore, there is a risk that accreditation bodies will require more than just highlighting the new area of content within dedicated courses within the degree. While this risk may be acceptable now, it may not be in future accreditation cycles if the requirements become more stringent. There is also a risk that by containing the new content knowledge within a few flagship courses, there is a low program resilience to events such as the course convenor resigning or going on sabbatical, or a low student regard for the course because it is too general, or trying to cover too much.

6.2.4.3 Supporting flagships with armada approaches

While flagship courses may be an attractive first step, they need to be supported by other courses in the program which reflect the flagship course's key message to provide students with an integrated learning experience that develops the required graduate attributes. It is possible, however, that staff not directly involved in the flagship course may regard this content as being sufficiently covered and as a result they may not seek to incorporate appropriate content from the flagship into their courses, leading to a disjointed overall curriculum.

Taking the military analogy a step further, while a 'flagship' flies the fleet's flag, the rest of the fleet, or 'armada' is just as important in making an impression on their target. Hence, in an armada approach to curriculum renewal new content areas are integrated across the range of courses as appropriate and not just the flagship. Indeed, a department may decide to adopt an overall flagship theme for an undergraduate degree program, such as 'Sustainable Energy Solutions', or more broadly 'Engineering for the Future'. In this case, courses within the program can be designed to systematically introduce and develop various aspects of this flagship theme.

As part of the progression towards EESD, a department may also decide to use several key courses from within the armada to build on the flagship theme, rather than trying to integrate sustainability into every course immediately. This still provides a clear pathway for developing graduate attribute knowledge and skills while the remaining courses are reviewed and renewed. In adopting this approach, the department will need to consider what the minimum number of supporting courses will be in the first instance (and hence what will be prioritised for curriculum renewal), to

provide a ‘critical mass’ of sustainability content that addresses the desired graduate attributes for the program.

Within the armada approach, the department may choose to use different strategies to integrate EESD, depending on the year level. For example, in first year, EESD integration may be addressed by ensuring that all course outlines contain a ‘meta-discourse’ or overarching discussion about the relevance of the course being offered to EESD. In addition, sustainability content may be developed and integrated into, or completely replace, examples or case studies that support existing curriculum, in each first year course, demonstrating the application of theory to emerging sustainable development requirements. For example rather than demonstrating the laws of thermodynamics through exploring the petroleum engine it might be demonstrated through exploring a cogeneration plant or heat exchanger.

At an intermediate or advanced level, an armada approach depends on whether the course requires minor, substantial, or major changes, depending on the outcome of an audit against graduate attributes, where:

– Minor changes may be addressed by introducing context or an additional dimension to the issues being discussed, or the calculations being undertaken. It may be sufficient to replace examples or case studies, and to ensure that the course outline and assessment includes appropriate language. For example, in a numerical methods course, this could involve bringing in programming that incorporates ‘performance optimisation’ or ‘resource consumption minimisation’ calculations, which may not have been considered previously. One or more examples may be integrated into the course, using ‘life cycle assessment’ or ‘energy efficiency’ in the problem formulation. Students may be set a problem such as this for their major assignment. It might then also be referred to in the end of semester exam.

– Substantial changes may be addressed by considering the issue of managing the time lag between training in sustainability content and the demand for graduates with this new knowledge and skill set. Initially, most graduates will still be expected to design and maintain ‘old industry’ products and services, and perhaps just understand current innovations. However, this is likely to shift over time, to a situation where most graduates will be expected to design and maintain ‘new industry’ products and services, with an understanding of what preceded it. In this way, a course requiring substantial changes may have the same title in 10 years time, but might have gradually replaced its content.

– Major changes, may be addressed by replacing the course, immediately, or at a strategic point in future. For example, a course on coal-fired power-stations may be run long enough to match the industry need but then may be replaced with a course on the design and maintenance of renewable energy options, with perhaps a small component on maintaining coal-fired power-stations as they are run through to the end of their design life.

Strategically integrating sustainability content across the program using the armada approach has a number of potential benefits. It assists the department to demonstrate a comprehensive approach to education for sustainable development, to the accreditation body. It can be used to demonstrate how a set of graduate attributes for a program are developed in each of the courses (i.e. the learning pathway). If coordinated with the flagship approach, the department could demonstrate how the key theme/s are reflected and developed throughout the remaining courses in the program, providing a clear and layered pedagogy that enhances the learning experience. Furthermore, it is a way for the department to cater for changing graduate skill requirements, by ensuring that course convenors continually review examples and case studies to ensure they are aligned with graduates' future work environment.

However, in adopting an armada approach, the department should consider a number of potential pitfalls. The approach needs commitment from a large number of staff, to amend lectures, tutorials, workshops, assignments, laboratories and site visits etc. There is a risk that if staff are not committed to such an integrated approach to curriculum renewal, then there will be a disconnect between those courses that do address sustainability, and those that don't, which could be confusing for students and detract from the program. The approach also needs to be strategic and structured to avoid redundancy and a disorderly revision of content. There is a risk that an unstructured approach could result in possible overlaps or gaps in sustainability knowledge and skills within the curriculum causing confusion and frustration to staff involved and students undertaking the courses. Whereas staff may teach with a 'course level focus', students may have a 'program wide focus' as they are exposed to all courses and can see how they do or don't interact and support each other.

The armada approach also needs to be coordinated to ensure that new content is aligned with regard to language, terms, definitions and overarching message, to provide a clear learning pathway for students. There is also the risk that if staff do not collaborate in the curriculum renewal process, the result will be a fragmented learning experience that does not effectively or fully develop the sustainability related graduate

attributes. It also needs to consider potential interactions with colleagues outside the department, potentially across a number of courses. Curriculum renewal towards EESD requires a multi-disciplinary approach drawing upon the need to acquire knowledge in science, economics and legal disciplines as well engineering, so time needed to involve other departments also needs to be taken into account.

6.2.4.4 Using existing supporting content resources

In considering curriculum development requirements, a department may be able to reduce costs by using existing external content and other online database, case study and portal resources, as described in Chapter 3 (Table 3.2).

There are a number of advantages of using pre-prepared content resources. For example, many resources have been critically reviewed, are academically rigorous, and are based on core competencies which don't require constant updating (minimising resources for course building and updating). Pre-prepared curriculum can also contain relevant, rigorous introductory material that is readily accessible for undergraduate, postgraduate and professional development offerings. The content can also include discipline-specific and leading edge materials which would otherwise take significant resources to develop in-house and can be altered in many cases to fit with the particular institutions preferred graduate attributes in the area.

The pedagogy of such materials can be very straight forward and flexible, making the materials easily accessible by lecturers. For example the material developed by The Natural Edge Project follows a standard format comprising the educational aim, followed by a list of optional/required reading, key learning points, followed by background information on the topic being considered to assist teachers in knowing the emerging literature, and students who may need extra tuition on the topic.[21]

However, there are a number of potential issues with using part or all of such pre-prepared lecture resources. For example, content may have been developed mainly for programs in specific countries, meaning that examples may be country, hemisphere, language, metrics or currency specific. Given the rapid development of technologies on sustainable development, some content may be out of date even over short periods of time and may require updating.

The cultural context may also be significantly different for departments engaging in curriculum renewal in different countries and with different student compositions. This variety requires contextually sensitive content, or content that can be relatively easily amended to suit the student audience. For example, a university in Africa may consider

using pre-prepared material on water scarcity and issues, developed in Australia. This content may contain facts and figures that are specific to Australia, which could be enhanced for an African audience through including references to local legislation and context, local constraints and opportunities, and local innovations. Depending on the availability of knowledge about the local environment, the pre-prepared content might also be augmented by additional lectures/ modules developed within the department, or parts of other pre-prepared material.

Currently the majority of content resources are provided in English, which is not the first language for many countries. While organisations such as *Japan for Sustainability (JFS)* are constantly translating emerging technologies between languages, there is a need for the development, promotion and perhaps also translation of quality resources to support engineering departments in making the transition to EESD.

6.2.5 Addressing barriers and benefits

As highlighted in Chapter 3 and the above paragraphs, there are a number of curriculum-related barriers to staging and implementing rapid curriculum renewal towards EESD in the classroom. A summary of key barriers and benefits observed in energy efficiency education and engineering education is summarised in Table 6-4.

Table 6-4. Summary of key barriers and benefits to rapid curriculum renewal

Summary of Barriers	Summary of Benefits
– Lack of available data/ information – Lack of time for preparation – An overcrowded curriculum – Prohibitive cost – Lack of knowledge – Lack of value attached – Lack of industry contacts – Resistance to top-down directive – Students' prior learning habits – Lecturer apathy – Administrative coordination	– Improved marketability – Cross-functionality of content – Additional research opportunities – Networking opportunities for students – Networking opportunities for lecturers – Experience in incorporating emerging concepts into curriculum – Addressing the time-lag for graduates – Improved pedagogy - problem based learning – Improved pedagogy – generic skills – Lecturer professional development

Source: Adapted from Desha, C., Hargroves, K. and Reeve, A. (2009)[22]

Putting in place mechanisms to address one defined barrier can have benefits for addressing other barriers. For example, for key staff who are tasked with integrating new content, setting up an annual allocation of teaching buy-out funds, or having an avenue for temporarily altering staff teaching-research-service workload allocation to engage in rapid curriculum renewal, would help to address the barrier of insufficient time for preparation. Similarly, an annual small-grants program available for educators

to pilot rapid curriculum renewal initiatives would help to address the barrier of prohibitive cost. With such considerations in mind, HEIs can strategically allocate budget and human resourcing to enable the integration of new content into existing education and training programs. For example this could be through a 'tiered' approach, where the first three options, including the use of case studies, guest lecturers and supervised research, may immediately be targeted, with other options then implemented among various programs in the following budget cycles.

6.2.6 Bridging and outreach

This element highlights the role of outreach and bridging, as a strategic way for departments to strengthen its identity and market its program/s, and to raise awareness among potential future students, both for undergraduate and post graduate courses, about its educational capabilities. As the curriculum renewal phase proceeds, the department may want to provide professional development opportunities among industry and government (i.e. bridging), which might also serve to raise awareness among potential employers and students about new program offerings. In addition, the department may also want to raise awareness about new course content with potential future students in industry and in high school (outreach).

Bridging and outreach activities may span all stages within the rapid curriculum renewal process, harnessing activities that are being used to contribute to awareness raising and developing a common understanding among staff. For example, external keynote lectures and university activities may be promoted as public events. However such activities should not pre-empt the ability of staff to adequately teach or train in the emerging knowledge and skill areas. Hence, this element will likely have a low to moderate focus in early stages with the department engaging with both industry and school representatives at this point. This then increases as curriculum development activities begin for the duration of the rapid curriculum renewal process.

6.2.6.1 Bridging opportunities with Industry and Government

Although few postgraduate programs require accreditation (and are therefore not under pressure by the accreditation organisation), there is strong and increasing pressure from industry and government for employee professional development in sustainability knowledge and skills. Hence the market is sending clear signals about demand for courses on particular topics and so the risk to engineering departments seeking to offer such courses is reduced, particularly if they are offered in partnership with other departments such as business or science.

Bridging could be undertaken on campus at the university, offered onsite, or offered online. The capacity building may be in the form of non-certificate short course training (on campus or onsite), or as a course that has the option for assessment and credit towards a postgraduate qualification. Such interactions with industry strengthen relationships with regard to future collaborative research endeavours, highlight to employers that graduates are being exposed to such new curriculum, and also facilitate awareness raising about new opportunities for study.

When considering bridging to industry and government, although the content may stay the same, the mode of content delivery is likely to need some modification towards adult learning principles. For example, adult learners, broadly speaking, share the characteristics of being self-directed learners who want knowledge that is immediately practical (i.e. problem centred), and who have a growing reservoir of experiences to draw on in learning.[23] Content delivery in these learning environments might immerse participants (both students and staff) in predicaments and problems that participants would bring with them from their workplaces, or other aspects of their lives. Such an approach makes access to online materials essential, together with staff support.

6.2.6.2 Bridging in undergraduate and postgraduate education

For institutions providing both postgraduate and undergraduate education, most postgraduate programs are often offered under a different fee structure to undergraduate programs, offering institutions more flexibility in being able to fund the development of new courses. Postgraduate programs often have courses that can be co-offered with final year undergraduate students, in particular while the level of sustainability knowledge across society is still low, and student needs are quite similar. Postgraduate courses are also often taught by staff who also teach undergraduate courses and thus content from courses such as those developed for industry, could then be used to gradually feed into undergraduate learning, while the masters and postgraduate content continues to be updated. Such a strategy allows for both undergraduate and postgraduate education for sustainable development to be continually improved as part of a curriculum renewal strategy.

An advantage of bridging postgraduate and undergraduate education in the curriculum renewal process is that departments can access the significant and increasing demand for continuing professional development opportunities in EESD across government, the industrial sector and licensing authorities to help fund and drive undergraduate curriculum renewal. The timeframe for post-graduate programs varies between 1 year for a diploma, to 3 years for a masters' certificate, meaning that students can relatively

quickly develop sustainability knowledge and skills, then apply their new knowledge and skills in the workplace. As masters students increase awareness about the need for colleagues with such knowledge and skill in their workplace, this may then increase demand for similar training, and also for graduates with such abilities. In this way, postgraduate curriculum forms a key component in undergraduate curriculum renewal.

A potential pitfall to consider in relation to bridging with industry is the potential for industry demand for short course training to undermine the department's capacity to deliver more formal post-graduate education (i.e. through staff resourcing). This can be addressed by creating short courses with a pedagogy that is rigorous enough to contribute to a post-graduate qualification. Such a strategy may also encourage consideration of further education such as a certificate, graduate diploma or masters.

Departments might also promote introductory and specialist courses internally to other sectors within the HEI, and to international potential student audiences through collaborations, as highlighted in the examples of organisations such as IR3S (Japan), ETHZurich's Centre for Sustainability (Sweden), Seoul University's International Urban Training Centre (Korea), the UK's Forum for the Future and LEADInternational, the International Water Centre (Australia) and United Nations University's Zero Emissions Research and Initiatives collaboration (see Chapter 3).

6.2.6.3 Outreach with high schools and the community

Most universities have existing programs to connect with their 'catchment' of potential students, through bridging activities such as accelerated final year programs for gifted students, and school outreach programs such as keynote lectures, competitions, open days and mentoring. Within this existing model, and in particular in the United Nations' Decade of Education for Sustainable Development, there are likely to be opportunities to engage potential students in sustainability topic areas taught by the department.

For example, the department could arrange for its first year flagship course/s to be offered to high achievers in high schools as an accelerated Year 12 course option. It could support existing sustainability challenges offered by local community groups, other institutions or government authorities, by providing prizes and keynote speeches on sustainability topics at events. Universities who do not have their own materials developed, can also immediately begin outreach activities with resources already available online. Extracurricular education programs, such as intensive short courses, can also play an important role in bridging the divide to potential students, and in introducing sustainability education in higher education. Finally, educational programs targeted at high school teacher professional development could also benefit both the

institution with regard to student numbers and awareness raising among teachers. Universities who do not have their own materials developed, can undertake outreach activities with resources already available online, as has already been done through UNESCO's *Teaching and Learning for a Sustainable Future* initiative, the ZERI Learning website, and the Australian *Teach Sustainability* website (see Chapter 3).

Universities will also need to continually adapt such outreach – and subsequent curriculum within university studies – to cater for changing incoming student knowledge and skills. Compared with 10 years ago, students already arrive at university with a greater awareness of sustainability. As such knowledge and skills become embedded in school education (i.e. from kindergarten through to year 12), and with increasing media exposure regarding the challenges and opportunities outlined in Chapter 1, student demands are likely to also change with regard to their preferred vocational education or higher education studies. This is therefore also an important consideration for universities considering outreach, and subsequent modes of integrating sustainability in engineering education over the next decade.

6.2.7 Campus integration

This element highlights the opportunities for curriculum renewal to be accelerated within the larger context of greening campus initiatives, and to also take advantage of momentum created by existing institutional change processes. As discussed in Chapter 3, the reality is that on average it is more likely that a high school is undertaking such on-campus sustainability projects than a university, and the students from such schools will be keenly aware of this lack of performance in selecting higher education options. However, as discussed in Chapter 1, universities can no longer afford to be seen to be teaching sustainability knowledge and skills, and then not practising it on campus (i.e. 'walking the talk'), given the significant potential for negative public relations and recruitment ramifications.

As for the previous element of bridging and outreach, this element should be included as a minor component of the early stages (i.e. Stage 1 and 2). This ensures that relationship building activities are commenced with campus facilities managers, and that future interaction opportunities are flagged and planned. Such activities may include inviting facilities managers to keynote lectures and staff workshops regarding EESD. Campus integration then becomes a focal point in the later stages (e.g. Stage 3 and 4), once staff begin to plan new content and campus interactions.

6.2.7.1 Taking advantage of existing campus greening initiatives

As noted in a report by the Australian Research Institute for Education for Sustainability (ARIES), for education institutions to more deeply address sustainability, campus management should be linked to research, curriculum and administrative practice, so that sustainability can be embedded across every aspect of institutional operations in a synergistic way.[24] The good news is that alongside curriculum renewal efforts, there are significant campus greening initiatives underway as highlighted in Chapter 3, primarily driven by a realisation of the cost-saving potential in reducing energy and water consumption. Many institutions are beginning to differentiate themselves by not just talking about sustainable development, but by practising what they teach.

However, this opportunity is complicated by the reality that the operational activities of most universities are vastly different to the academic systems surrounding teaching and research, from accounts through to management committees, often only having common reporting structures at the level of university senior executive (i.e. through pro vice-chancellors to the vice-chancellor or president). Hence, there is much scope for improvement in this regard: beginning with sharing knowledge about both campus operations and areas identified for potential improvement; teaching and research activities that may overlap with regard to potential on-campus projects that might be financially attractive as a cheaper implementation option for facilities management; and an opportunity to involve students from the academic perspective. In engineering education this may include for example opportunities to audit the energy or water consumption of buildings on campus, calculating the potential costs and energy savings of onsite renewable energy options, water saving infrastructure and passive cooling initiatives (such as shading, or painting the roof white or a lighter colour).

With many future leaders spending time on higher education campuses, greening campus efforts that involve students can yield educational dividends for the future, fast-tracking student experiences in real-life applications of the theory that they are being exposed to, and providing a supportive environment to address barriers surrounding dealing with new and emerging technologies. In a professional environment where staff may not have recent industry experience, on-campus initiatives can also provide staff with practical experience in their subject matter. For engineering education, where the majority of staff have not had practical experiences for 10 years or more, such experience can also be important in providing professional development opportunities in their discipline, and also to build off-campus networks with industry, business and government who may also be interested in piloting new technologies on campus.

6.2.7.2 Taking advantage of other campus change initiatives

In addition to taking advantage of those sustainability activities already being undertaken on campus, rapid curriculum renewal for sustainable development may also benefit from utilising other change processes underway within the institution. These may include for example, other teaching-related initiatives that encourage curriculum renewal, other restructuring endeavours which involve reviews and changes to offered courses and programs, and institutional benchmarking initiatives, which may already be investigating how the institution can improve its ranking among other universities. Staff turnover may also be considered an opportunity to review programs for desired candidate strengths.

6.3 Conclusion

In this chapter a model for rapid curriculum renewal has been presented as a way to update engineering education to deliver engineering graduates with the knowledge and skills required to underpin a prosperous society in the coming century. Using the findings of the previous chapters and building on the Sustainability Helix for organisational change, the model presents a directional but integrated and flexible approach to help organisations to address periods of intense curriculum change. It also highlights the complex and asynchronous nature of accelerated curriculum renewal, where stages allow for sometimes random and sometimes fully planned interactions

Through the model it is evident that each of the elements of curriculum renewal identified in this thesis has a role to play. However, the elements will not ensure 'rapid' curriculum renewal by themselves. Rather, they need to be supported by one or more catalysts (such as accreditation, regulation and employment) that set the timeframe for rapid curriculum renewal to occur. Furthermore, institutional leadership and support is also critical to ensure that the timeframe is translated into strategic planning and sustained implementation. Finally, a strategic approach is essential to avoid costly and resource intensive process that achieve sub-optimum outcomes.

Within this model, a number of considerations for implementation have been discussed for each element in turn, including timing and barriers and benefits. Departments seeking to rapidly embed sustainability into engineering curriculum could consider the model and its conceptual areas at the outset, to develop a strategy that is suited to its institutional and cultural context.

In conclusion, this model highlights the potential for strategic planning for rapid curriculum renewal towards EESD, and in doing so respond to current and emerging knowledge and skills shortages. It also highlights the key role of timeframe catalysts, institutional leadership and support, and employment in ensuring the success of rapid renewal processes. This propositional knowledge is discussed further in Chapter 7, together with implications arising from the model and opportunities for further research.

References

[1] Hargroves, K. and Smith, M. (2005) Chapter 10 'Operationalising Natural Advantage through the Sustainability Helix', in *The Natural Advantage of Nations: Business Opportunities, Innovation and Governance in the 21st Century*, Earthscan, London, pp161-164.

[2] Davis, R. and Savage, S. (2009) 'Built Environment and Design in Australia: Challenges and Opportunities for Professional Education', proceedings of the 20th Australasian Association of Engineering Education conference, 6-9 December, Adelaide, pp795-802.

[3] Australian Deans of Built Environment and Design (2008) *Review of Australian Higher Education*, ADBED, Canberra.

[4] Australian Deans of Built Environment and Design (2008) *Review of Australian Higher Education*, ADBED, Canberra, p4.

[5] Higher Education Council (1996) *Professional Education and Credentialism*, National Board of Employment, Education and Training (NBEET), Canberra, p4.

[6] Australian Federal Department of Resources, Energy and Tourism (DRET) 'Energy Efficiency Opportunities', www.ret.gov.au/energy/efficiency/eeo/pages/default.aspx, accessed 17 July 2009..

[7] Victorian Environmental Protection Agency (undated) 'Environment and Resource Efficiency Plans – EREP'.

[8] Council of Australian Governments (2009) *National Strategy on Energy Efficiency,* July 2009, Commonwealth of Australia.

[9] Smith, M., Hargroves, K., Stasinopoulos, P., Stephens, R., Desha, C. and Hargroves S. (2007) *Energy Transformed: Sustainable Energy Solutions for Climate Change Mitigation*, The Natural Edge Project (TNEP), Australia.

[10] The Institution of Engineers Australia (undated) 'Energy Efficiency: The Importance of Energy Efficiency in Moving toward Sustainability', The Institution of Engineers Australia website.

[11] The Campus Sustainability Assessment Project (undated) 'Introduction: The Sustainability Imperative and Higher Education: The Challenge of Sustainability', http://csap.envs.wmich.edu/pages/intro_imperative.html, accessed 27 June 2008.

[12] King, R. (2008) *Addressing the Supply and Quality of Engineering Graduates for the New Century*, The Carrick Institute for Learning and Teaching in Higher Education Ltd, Sydney, p30.

[13] Lattuca, L., Terenzine, P. and Fredricks Volkwein, J. (2006) *Engineering Change: A Study of the Impact of EC2000, Centre for the Study of Higher Education*, The Pennsylvania State University, ABET, Baltimore, MD.

[14] Fisher, R. and Ury, W. (1981) *Getting to Yes: Negotiating an Agreement without Giving In*, Random House, Great Britain.

[15] Desha, C. and Hargroves, K. (2008) 'Education for Sustainable Development Curriculum Audit (E4SD Audit): A Curriculum Diagnostic Tool for Quantifying Requirements to Embed SD into Higher Education - Demonstrated through a Focus on Engineering Education', UNESCO International Centre for Engineering Education (UICEE), *World Transactions on Engineering and Technology Education*, vol 6, issue 2, pp 365-372.

[16] International Engineering Alliance (2007) *Rules and Procedures: International Educational Accords,* International Engineering Alliance, pp40-41, *www.washingtonaccord.org/rules-and-procedures-aug-2007.pdf,* accessed 3 July 2008.

[17] ATSE (1997) *Government Submission on Education and Sustainable Development*, Australian Academy of Technical Societies and Engineering, Report prepared by a Sub-Committee set up jointly by the ATSE Committee on Sustainable Development and the Committee on Education for Technological Sciences and Engineering, www.atse.org.au/index.php?sectionid=585, accessed 25 July 2008.

[18] Kronholz, J. (2008) 'US Universities Face Turbulent Times Ahead', *The Wall Street Journal*, Career Journal

Section,www.imdiversity.com/villages/Careers/articles/collegejournal_highered_outlook_0305.asp, accessed 15 September 2008.

[19] Ferrer-Balas, D., Adachi, J., Banas, A., Davidson, C., Hoshikoshi, A., Mishra, A., Motodoa, Y., Onga, M. and Ostwald, M. (2008) 'An international comparative analysis of sustainability transformation across seven universities', *International Journal of Sustainability in Higher Education*, vol 9, Issue 3, Emerald Press.

[20] General meaning obtained from the HMS Victory website at: www.hms-victory.com/index.php and www.lib.mq.edu.au/digital//lema/maritime/shiptypes.html, accessed 31 July 2008.

[21] The Natural Edge Project (undated) 'Curriculum and Course Notes', www.naturaledgeproject.net, accessed 3 March 2010.

[22] Desha, C., Hargroves, K. and Reeve, A. (2009) *An Investigation into the Options for Increasing the Extent of Energy Efficiency Knowledge and Skills in Engineering Education*, Report to the National Model for Energy Efficiency, The Natural Edge Project (TNEP), Australia.

[23] Smith, M. (1999) 'Andragogy', The Encyclopaedia of Informal Education, www.infed.org/lifelonglearning/b-andra.htm, accessed 11 September 2008.

[24] Tilbury, D., Keogh, A., Leighton, A and Kent, J. (2005) A National Review of Environmental Education and its Contribution to Sustainability in Australia: Further and Higher Education—Key Findings, Australian Government Department of the Environment and Heritage and Australian Research Institute in Education for Sustainability (ARIES), p1.

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7. Conclusions

In this dissertation, the process by which program-wide curriculum renewal takes place in higher education was investigated, specifically in engineering education, in urgent and challenging times. In this chapter the overall conclusions are presented, including a discussion of the interpretive findings and subsequent requirements for broad testing and analysis. The chapter begins with a brief summary of the research which included literature review, narrative inquiry and peer review. This is followed by a series of propositions that identify future research opportunities to test the model. This propositional knowledge is then used to discuss implications of the research for a number of stakeholders across academic institutions, accreditation agencies, and government, in putting the model of rapid curriculum renewal into practice.

7.1 Summary of research

The dissertation explored a case account of a sociological phenomenon, namely the need for sustainable development knowledge and skills to be embedded within curricula, especially within engineering education. In this case, personal experience suggested a shortfall in engineering education for sustainable development (EESD) and subsequently an urgent need for curriculum renewal in this area. A review of literature regarding 21st Century challenges (Chapter 1) found strong evidence of a critical and extra-ordinary role for all professions to urgently help society address a multitude of emerging issues of sustainable development. The literature review also found clear evidence of Higher Education Institutions (HEIs) around the world facing increasing pressure from a variety of sources, including professional bodies, industry, government, and prospective students, to urgently equip graduates with knowledge and skills to address such challenges. A time lag dilemma was observed for the higher education sector, particularly in engineering education, whereby the timeframe for producing graduates with the required knowledge and skills lags behind the demand for graduates with such knowledge and skills – and indeed the timeframe within which the profession is expected to have acquired this increased capability. This was also evidenced in the findings of several key international surveys over the last decade.

A variety of catalysts or ‘drivers’ for accelerated curriculum renewal were identified:

– Market/ Business drivers: including shifting requirements by potential employers, and increasing student demand and market potential.

– Information/ Technology drivers: including increasing faculty interest in research and teaching innovation, and increasing focus in declarations and conferences.

– Institutions/ Civil Society drivers: increasing professional advocacy, shifting professional organisation requirements, shifting accreditation requirements, and increasing action by university peers.

These drivers were found to be interacting in complex ways with a number of barriers:

– Market/ Business barriers: including persistent 'old economy' industry practices, perceived threat to employability and position, short-termism in the HEI sector, and a shortage of engineering graduates.

– Information/ Technology barriers: including growing disconnect between engineering and science, lack of convenient access to emerging and rigorously reviewed information, and lack of access to information in other languages.

– Institutions/ Civil Society barriers: including lack of legislative or regulatory requirements for change, lack of institutional requirements for change, and lack of academic staff competencies in EESD.

Given these findings, a focus on EESD was concluded to be appropriate, with future potential application to a variety of other disciplines facing similar urgent and challenging circumstances.

In Chapter 3, an integrative literature review of curriculum renewal literature was used to ask what was evident in the literature regarding elements of curriculum renewal. It was concluded from the literature review that although there is evidence of frustration with the current 'slow' process, in the absence of documented discourse about dealing with potential time constraints, no alternative is discussed. Despite discourse about timing issues existing for more than four decades, it was concluded that although the field is focused on the issues of systematic curriculum design and development, there is little consideration for the speed at which curriculum is constructed and implemented or reviewed. While existing models provide significant guidance on systematic curriculum construction, none consider – either explicitly or implicitly – how to vary the pace at which curriculum renewal may be undertaken.

It was hypothesised from this review that if there are emergent processes that have not yet been captured in systemic considerations of rapid curriculum renewal, then they should be evident in documented experiences of curriculum renewal. Subsequently EESD literature was reviewed with regard to how rapid curriculum renewal was attempted. It was concluded that there are a number of mechanisms, which could be grouped under a number of themes or 'elements' of curriculum renewal. Secondly, higher education literature was reviewed to learn from other professional discipline experiences including law, business, nursing and medicine, where curriculum had

clearly been renewed in urgent and challenging times. A number of mechanisms were distilled which were then considered together with the mechanisms identified for the engineering examples, resulting in a set of six elements evident in time-managed curriculum renewal processes, extending the discourse on ‘curriculum in context’.

It was also concluded from the contextual and integrated literature reviews that a number of catalysts play a critical role in ensuring that the use of the elements result in rapid curriculum renewal; namely program accreditation, regulation and policy, and employment. There are also several important staging and implementation considerations to address a number of identified barriers to the process, taking a holistic, non-linear and integrated approach to using the elements. Ultimately, institutional leadership and support is also critical in ensuring that an institution adopts a process of rapid curriculum renewal, setting and meeting the planned milestones.

A process of formal reflective inquiry was undertaken into personal experiences in attempting curriculum renewal as an educator and researcher to further inform the literature findings (Chapter 4). This included reinforcing or contradicting aspects that were already discussed in the literature, and potentially uncovering phenomena that may not be apparent in the existing literature on curriculum renewal. In considering the questioning profile, there were a number of realisations about the practicalities of rapid curriculum renewal that added to the learning from the literature review, in particular with regard to the role of catalysts, leadership and strategic implementation.

It was also realised from the reflexive inquiry process that an existing schematic for an organisational change model could be adapted to provide a schematic for the model for rapid curriculum renewal. Not only does this helix provide the sense of non-linear dynamism necessary within the higher education industry; it also demonstrates the non-linear behaviour of the elements of curriculum renewal, intertwining in a complex pathway, which is highly dependent on the organisational structure and context, but moving towards the goal of rapid curriculum renewal.

A process of extensive peer review (Chapter 5) was undertaken alongside the literature review and reflexive inquiry processes, to ensure that the findings regarding the model and component elements are credible. This process highlighted a number of further minor considerations that were subsequently embedded within the model description (Chapter 6). It was confirmed from the peer review process that the model makes a contribution to engineering education theory, through presenting elements that can be used to accelerate curriculum renewal processes, subject to the presence of sufficient catalysts, and staged strategic implementation that has institutional leadership and support.

7.2 Propositional Knowledge

In considering potential application of the model within higher education institutions, it is clear from the barriers highlighted in the literature review (Chapter 1) that there are still few catalysts that are large enough to drive rapid curriculum renewal in engineering education. This is perhaps comparable to the school curriculum reform process in Australia, where it has taken almost three decades for the catalysts to become great enough (including politicians, policy makers, and educators on both sides of politics) to trigger a period of 'rapid curriculum planning' in 2009 for national reform. As discussed in Chapter 3, this has included more than 20 years of calls for national curriculum reform. Subsequently by 2012, the plan for national curriculum will be released, for implementation over the next two decades.

Considering the case of EESD it is difficult to predict when the trigger will occur globally, but as previously discussed (Chapter 1, Figure 1.2), the literature suggests that the shift in market and regulatory requirements is likely to occur within the next 5-10 years. With this timeframe in mind, for some countries the findings of this study may be slightly pre-emptive of a mainstream shift (i.e. 'pre-t'), when institutions are acting in relative isolation. However, for other countries, significant catalysts are already at work, with institutions already using one or more of the elements in the model.

Within this context, the following four propositional statements have been abstracted from the model's four conceptual areas, which need to be addressed for rapid curriculum renewal, in the order of 6-8 years rather than 15-20 years, to be achieved:

1) *There is a need for one or more catalysts to set the timeframe within which rapid curriculum renewal is to occur.*

   The model itself does not guarantee a rapid transition to EESD, as there is the potential to use elements within the model with long time horizons that are still in the order of up to 20 years. Clearly, whether or not the model will be useful for rapid curriculum renewal depends on whether there are strong enough catalysts that set clear timeframes for the transition.

   Although accreditation is currently one of the strongest potential drivers of change, the reality is that accreditation is still relatively weak in expectations, being more likely to incrementally affect the status quo rather than revolutionising it. It is therefore unlikely that rapid curriculum renewal will be successful in institutional settings without catalysts other than accreditation. Hence the role of government, industry, the institutions themselves and students that can make it happen. For example a large multi-national could offer a large sum of money for a local

university to overhaul the curriculum. Other catalysts could include changing the assessment requirements to be more aligned with assessing sustainable development knowledge and skills.

2) *Institutional leadership and support is essential to reduce the barriers associated with rapid curriculum renewal.*

The model relies on institutional leadership and support to establish timeframes for curriculum renewal within the institution, and to set the momentum and reduce the many organisational barriers to rapidly embedding new content into curriculum. The form of such support will be unique for each HEI. University support could include the provision of funding, marketing and resources, and flexibility in rules regarding developing new courses and modifying existing courses.

Those institutions considering the model in the period 'pre-t' may find it more difficult to set substantial short term goals and allocate budget for curriculum renewal such as graduate attribute mapping and curriculum auditing. Furthermore, these institutions may find it difficult to secure government and industry financial support for innovative renewal initiatives, relying on harnessing momentum from existing institutional projects. Ideally, institutional support would be available at all levels within the institution, from the department through to the university's executive council, encouraging strategic engagement with the elements in the model, and supporting staff who are amenable to engaging with rapid curriculum renewal processes through mechanisms such as workload reallocation, assistance with professional development, and teaching buy-out.

3) *A number of elements need to be considered within the process, systemically and synergistically rather than in isolation.*

The model is reliant on the successful interaction of six elements of curriculum renewal which have been shown in the literature and through personal experience to contribute to accelerated curriculum renewal. These elements comprise: scoping and awareness raising; graduate attribute mapping; curriculum auditing; content development and renewal; and campus integration.

Although there is no prescriptive checklist for when and how the elements need to be implemented, the elements need to be considered holistically rather than in isolation, to achieve rapid curriculum renewal. This may include activities that occur in parallel, that are synchronous or asynchronous, based on each institution's existing frameworks and curriculum renewal systems. Ideally if an institution is embarking on curriculum renewal towards ESD with no previous initiatives, then

systematic consideration will facilitate rapid curriculum renewal within 6-8 years as discussed in Chapter 6.

4) *The application of the elements needs to be staged, with clear milestones that can be reviewed and reported against.*

The model uses stages to ensure that the process of rapid curriculum renewal can be planned to fit within the allocated timeframe. Ideally the strategic planning for such staging will consider how the three phases of curriculum renewal discussed in Chapter 3 (i.e. ad hoc, flagship, and integration) will be contracted.

For example, Stage 1 (0-6 months) could comprise the completion of initial internal capacity building. Stage 2 (6 months - 1 year) could comprise the completion of internal status reporting and graduate attribute mapping. Then, by Stage 3 (1 - 1.5 years) the curriculum auditing could be completed and bridging and outreach could have commenced with school and industry. In Stage 4 (1.5 - 3 years) strategic content development could have been completed for the first year intake to complete a renewed program, with the renewed program producing its first graduates by the sixth year.

Ideally this process of rapid curriculum renewal would result in a non-confrontational, pro-active and outcomes-based approach that preserves institutional diversity and innovation. Planning from the outset, the department would determine the best approach given the opportunities and risks with niche degrees versus embedding content across the degree, using either a flagship and/or integrated approach. Flagship and armada course content would be developed to achieve a critical mass of sustainability content as quickly as practicable, accessing the growing online library of academically rigorous open-access teaching and learning resources to accelerate course development and renewal. The department would build a strong collaborative foundation across campus sub-communities as an important mechanism to successfully address issues as they arise during the curriculum renewal process.

Bridging and outreach activities would be undertaken across industry and government, undergraduate and postgraduate programs, and high schools and the community, to recruit students to the renewed programs, making use of national and international collaboration with other academic institutions and non-profit organisations, to jointly deliver courses on sustainability topics. The process would harness existing opportunities and create others to integrate EESD into campus operations as a two-way collaboration between academics and students, providing students and faculty with first-hand experience in applying sustainability principles.

7.3 Potential implications of the research findings

This thesis is based on the premise that issues of sustainability and role of engineering are both critical, and furthermore education of engineers to address these issues is a world-wide problem. With the future wellbeing of society in mind, this model and associated propositions need to be considered by educators world-wide, to improve the potential for rapid curriculum renewal. This is particularly so with regard to the distilled elements of curriculum renewal promoting rapid curriculum renewal processes, but also with regard to the three other important conceptual areas which were uncovered through the research, namely: the role of timeframe catalysts, institutional leadership and support, and the need for strategic staging.

The following paragraphs highlight potential implications of this thesis for various sectors of society involved in EESD, ESD and other time-constrained curriculum renewal initiatives. A number of research needs arising from the tentative and propositional outcomes are also highlighted, including further exploration of the other three conceptual areas noted above.

7.3.1 Engineering education for sustainable development

Building on from this research, there are a number of potential areas for further investigation which would also support existing research projects underway in Australia. These are summarised in the following points:

– *Trialling the elements of the model*: Each of the elements of curriculum renewal has been described with reference to the literature and personal experiences. This description of the element, and the practicalities of using it to undertake rapid curriculum renewal, could be further enhanced through action based research and reflection by others on their curriculum renewal experiences in engineering education. An example of an opportunity is provided in New South Wales, where the NSW Department of Environment, Climate Change and Water has taken the results of the National Framework for Energy Efficiency (NFEE) report on barriers and benefits to embedding energy efficiency into engineering education,[1] to seek funding proposals from engineering faculty in New South Wales on projects to trial curriculum renewal in this area.

– *Further enhancing the theory associated with the preliminary model for rapid curriculum renewal:* This might involve further consideration of how the proposed model builds on the concept of ‘curriculum in context’ and how it complements and challenges existing philosophical constructs of curriculum renewal. For example, a

2008 ALTC project on 'Design based curriculum reform within engineering education' (UNSW, QUT, University of Melbourne and University of Sydney) is based on the CDIO model, involving a detailed comparative study of engineering curricula at four Australian Engineering Faculties, to inform renewal of Australian engineering curriculum.

– *Investigating the role of accreditation in driving rapid curriculum renewal:* This dissertation has included some discussion on the role of accreditation as a potential major catalyst for rapid curriculum renewal. However, the role of accreditation could be further investigated to understand how it can best be used to catalyse change. There are a couple of research initiatives currently underway in Australia that are considering the need for changing accreditation requirements.

  In 2008 an Australian Learning and Teaching Council (ALTC) project on 'Curriculum specification and support systems for engineering education that address revised qualification standards' commenced, led by the University of Technology Sydney and involving a large consortium including Engineers Australia, the Australian Council of Engineering Deans, and the Australasian Association of Engineering Education. This project is now considering revising national competency standards and broad program specifications, and guidelines for new and revised program pathways.

  In 2009 the University of Southern Queensland and the University of Tasmania commenced an ALTC project on 'DYD: Defining Your Discipline to facilitate curriculum renewal in undergraduate programs', which explores how discipline specific graduate outcomes can be developed that expand on the generic graduate attribute statements defined for all engineering disciplines, to help focus curriculum renewal efforts in meeting accreditation requirements. This project may in turn help to review national requirements by providing an interpretation of what they do and do not include at a discipline-specific level.

– *Investigating supporting government policy mechanisms:* In this research, reference has been made to the potential for national guidance to also contribute a catalyst role to instigating rapid curriculum renewal. Further research could be undertaken to consider policy mechanisms that could be used to encourage rapid curriculum renewal towards EESD. Such research would build on a number of research initiatives recently completed. For example, in 2006 led by Professor Johnston (University of Technology, Sydney) and the Australian Council of Engineering Deans undertook a project on 'Ensuring the supply and quality of engineering graduates with attributes for the new Century', researching factors that would help

ensure that the education sector produces graduates with appropriate attributes for 21st Century engineering.[2]

These potential research opportunities may be further expanded subsequent to the publication of the model and elements, which is planned for release in 2010 through Earthscan Press. Through the publication development process, contributions have been received from more than 40 engineering educators internationally, within which exist several opportunities for future international collaboration. International forums such as the United Kingdom's 'Sustainability in Higher Education' (SHED) network also have newsletters which could be used to seek comment on the model.

7.3.2 Education for sustainable development

The findings of this research are particular to the topic of education for sustainable development within engineering education. However, as discussed in Chapter 1, there are many other professions (for example including law, business, nursing and medicine) and sectors of society (for example schools and vocational education) facing similar pressure to incorporate emerging knowledge and skills related to sustainable development. The potential for wide-scale application is also apparent when considering that there are approximately 60 million teachers in the world spanning kindergarten through to higher education, and the majority have been trained through the higher education system.[3] Building on from the findings of this dissertation, the following text highlights how these sectors in particular could consider how the model might support rapid curriculum renewal (key Australian research links are noted):

– *Investigating the applicability of the model and its elements to other professional disciplines considering ESD:* There are other professional disciplines which are also facing pressures to renew their curriculum to address similar challenges, as highlighted in Chapter 1. Hence, further research could be undertaken on the concept of rapid curriculum renewal for education for sustainable development in higher education, building on current research underway. For example, in 2007 Associate Professor Savage led an ALTC project on 'Professional education in built environment & design' (QUT, Curtin, RMIT, UNSW, University of SA, UTS), which examined key issues facing built environment professionals and education among participating universities, including education for sustainable development. In 2009, the University of Tasmania, Murdoch, UNSW, and the University of Wollongong undertook an ALTC project on 'Demonstrating distributed leadership through cross-disciplinary peer networks: responding to climate change complexity'. Extending a previous trial in Tasmania, this trial is seeking to embed distributed leadership

development as 'business-as-usual', facilitating student learning around climate change issues.

– *Investigating the applicability of the model and its elements to K-12 providers:* There are also other sectors facing pressure to undertake rapid curriculum renewal, in particular Kindergarten to senior high school (i.e. K-12) education providers, where the professional development of teachers in education for sustainability has been identified as 'the priority of priorities'.[4] The federal government has initiated several schemes, including the Australian Sustainable Schools Initiative (AuSSI), along with strategies such as 'Educating for a Sustainable Future: A National Environmental Education Statement for Australian Schools' (NEES)[5] and 'Living Sustainably: The Australian Government's National Action Plan for Education for Sustainability'.[6] Hence, this research could be extended to consider how the elements might relate to other sectors such as school education providers. This also has implications for teacher education at university (fitting into the above bullet point also), for which research is currently underway through ARIES, on pre-service teacher education, funded by the Department of the Environment, Water, Heritage and the Arts.[7]

– *Investigating the applicability of the model and its elements to other further education providers:* Alongside professional education, technical and vocational education and training (TVET) providers are also grappling with the significant challenge of embedding sustainability knowledge and skills within their programs, as highlighted by the NSW Department of Education and Training in their 2009 report 'Skills for Sustainability'.[8] The model outlined in this dissertation could be further researched for potential application within TVET, to facilitate the rapid curriculum renewal required in this sector. Given the regulated learning outcomes for many vocational education courses in sustainability technologies (for example including trades requirements to ensure installations are fitted correctly and warrantees are not voided), the structured programs and institutional environment, it is anticipated that the model might be readily adaptable.

Internationally, research opportunities exist to explore the model in more detail. For example, the UNESCO Chair 'Higher Education for Sustainable Development' hosted the 3rd International Conference on Higher Education for Sustainable Development in Malaysia, which included 12 case study presentations on research related to curriculum renewal from both developing and developed countries. The American Association for Advancement of Sustainability in Higher Education (AASHE) regularly

profiles research relating to ESD, which could also be explored for further international collaborations.

7.3.3 Curriculum renewal in urgent and challenging times

The findings of this dissertation are specific to curriculum that is heavily regulated and which undergoes incremental change as an evolutionary – rather than revolutionary – timescale. Moreover, the distilled elements of rapid curriculum renewal are process rather than content related. It is anticipated that they will be employable wherever there is an imperative for urgent change regarding any new knowledge and skills that are complex; not just the 21st Century challenges discussed in this dissertation.

Hence, building on from this dissertation, there is the potential for higher education providers to consider applying the model for rapid curriculum renewal for any professional discipline facing curriculum renewal in urgent and challenging times, transcending boundaries between disciplines and continents. For example, this could be undertaken through a standard sociological study of the effects of implementing the model. Several examples of Australian research which could be furthered by such investigations include:

– *Investigating the applicability of the model and its elements to law education:* As discussed in Chapter 3, legal practitioners are facing significant challenges in a rapidly changing world with regard to outdated education systems. In 2005, An ALTC project on 'Learning and teaching in the discipline of law: achieving and sustaining excellence in a changed and changing environment' (Flinders, Council of Australian Law Deans) examined key characteristics of law students, and processes for improving awareness and desired learning outcomes. Most recently in 2009, led by Professor Kift from QUT, an ALTC project commenced, titled 'Curriculum renewal in legal education: articulating final year curriculum design principles and a final year program' (QUT, Griffith, UWA).

– *Investigating the applicability of the model and its elements to business education:* As discussed in Chapter 3, recent phenomena such as the global financial crisis, fair trade and corporate social responsibility have created a significant challenge for business education to provide contemporary education, which is being explored in education research. For example, in 2007 an ALTC project on 'Facilitating staff and student engagement with graduate attribute development, assessment and standards in Business Faculties' (UTS, QUT, UQ, UoS) commenced, which developed a Business oriented graduate attribute integration process using a pre-existing online assessment system.

- *Investigating the applicability of the model and its elements to Occupational Therapy:* A 2007 project on 'Mapping the future of occupational therapy education in the 21st century: review and analysis of existing Australian competency standards for entry-level occupational therapists and their impact on occupational therapy curricula across Australia' (UQ, JCU) developed recommendations for a revised set of competency statements for entry level occupational therapists, to reflect contemporary and future practice in Australia.
- *Investigating the applicability of the model and its elements to information, communication and technology (ICT) education:* With the rapid emergence of internet and communication technologies, there is an increasing focus on curriculum renewal issues in the education sector. For example, in 2006 an ALTC project on 'Managing educational change in the ICT discipline at tertiary education level' studied the nature of change with the ICT discipline and impact on the university curriculum from the perspectives of educational preparation (high school), university educational experience, preparation for the workplace, and the needs of employers.[9]

There is also the potential for this model to be considered within learning and teaching departments in the higher education institutions, with regard to how rapid curriculum renewal can be encouraged at a school level. For example, follow-on research from a 2008 ALTC project on 'Leading curriculum renewal, redesign and evaluation: The development of a guide for academic leaders in Australian universities' might include consideration of the concept of rapid curriculum renewal in curriculum leadership.

There is not yet a significant literature that auditing a program will lead to curriculum renewal or improved graduate capabilities in sustainable development. To rigorously demonstrate this case for EESD would involve a significant longitudinal behaviour change research project comprising a number of engineering departments internationally, including those who have decided to proceed with the transition (i.e. the trial group), and others who have decided not to (i.e. the control group). For example, the trial group could undertake an audit of one or more programs, and then track curriculum modifications and the capabilities of graduates against a pre-determined set of 'graduate attributes' through subsequent audits.

Finally, there is the potential for similar research initiatives underway internationally to consider the implications of rapid curriculum renewal and the model elements. In particular the international CDIO initiative could further its investigation of how to embed emerging knowledge and skills into engineering curriculum, to consider how to systematically achieve a rapid process of integration when necessary.

References

[1] Desha, C., Hargroves, K. and Reeve, A. (2009) An Investigation into the Options for Increasing the Extent of Energy Efficiency Knowledge and Skills in Engineering Education, Report to the National Framework for Energy Efficiency, The Natural Edge Project (TNEP), Australia.

[2] Johnston, A. (2008) *Addressing the supply and quality of engineering graduates for the new century,* report to the Carrick Institute from the Australian Council of Engineering Deans.

[3] United Nations Educational Scientific and Cultural Organisation (UNESCO) (2002a) Education for Sustainability - From Rio to Johannesburg: Lessons learnt from a decade of commitment.

[4] UNESCO-UNEP (1990) Environmentally Educated Teachers: The priority of priorities, Connect Vol XV, No 1, pp1-3.

[5] Australian Government and Curriculum Corporation (2005) *Educating for a Sustainable Future: A national environmental education statement for Australian schools*, Department of the Environment and Heritage, Canberra.

[6] Australian Government (2009) *Living Sustainably: The Australian government's national action plan for education for sustainability*, Department of the Environment, Water, Heritage and the Arts, Canberra.

[7] Ferreira, J., Ryan, L., Davis, J., Cavanagh, M. and Thomas, J. (2009) *Mainstreaming Sustainability into Pre-service Teacher Education in Australia*, prepared by the Australian Research Institute in Education for Sustainability for the Australian Government Department of the Environment, Water, Heritage and the Arts, Canberra.

[8] NSW Board of Vocational Education and Training (2009) *Skills for Sustainability,* 2nd Ed, NSW Department of Education and Training, Sydney.

[9] Koppi, T. and Naghdy, F. (2009) *Managing educational change in the ICT discipline at the tertiary education level*, report to the Australian Teaching and Learning Council, Support for the original work was provided by the Australian Learning and Teaching Council, an initiative of the Australian Government Department of Education, Employment and Workplace Relations.

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Postscript

I have attempted in this thesis, to examine my experiences as the research instrument, triangulating the perspectives of what I am seeing as critical elements of rapid curriculum renewal with the literature and with researchers in the field. Reflecting on the Prelude, the content of this thesis, and the five years in which I have explored the research question, I recognise that through these experiences as a researcher and an instrument, there has also been an effect upon me, in addition to what I have found, as discussed in the following paragraphs. Such reflection on how my positions and values declared at the outset of the research have been affected by the research process and findings provides a necessary bookend to the Prelude, helping to demonstrate transparency, confirmability and credibility in my narrative approach to this research.

Since beginning the thesis research, I have transitioned from a graduate engineer and novice lecturer to having six years' teaching experience. Over these years my personal appreciation of institutional constraints such as bureaucratic processes for curriculum renewal, teaching support and buy-out, tensions between teaching versus research, additional challenges of existing students needing to be accommodated, and promotion incentives has increased substantially, raising my awareness of challenges and affecting my view on plausible timeframes for rapid curriculum renewal.

In particular, I have come to understand that despite widespread calls for urgent action, for most institutions curriculum renewal is still an evolutionary rather than revolutionary process due to institutional and individual-related barriers that delay and obstruct. This is particularly so when considering curriculum as the 'actualised' learning experience (as opposed to the completion of documentation), which is not likely to change in the absence of significant external catalysts. Moreover, while accreditation is most likely to be the most influential single catalyst for engineering, even if did require program-wide curriculum renewal for all disciplines, in reality this would still amount to a process spanning 2 – 3 accreditation cycles (i.e. 10-15 years).

Hence, with current accreditation and other external catalysts, an accelerated renewal timeframe for an institution, using the identified elements and model, is still likely to be longer than my desired rapid curriculum renewal process of 6-8 years (i.e. such that graduates can contribute to change as they progress through their careers, within 10-15 years of entering university). However, any program-wide curriculum renewal process that can proceed within 2-3 accreditation cycles is still more than double the rate of current incremental and *ad hoc* processes underway in most engineering departments around the world.

Over the course of the doctorate, I have also transitioned to an academic researcher with a number of project experiences and publications that rigorously document research into rapid curriculum renewal. Face to face interaction with mentors in the field in addition to hundreds of hours reading about experiences of others around the world, have helped me develop confidence to put forward my model and propositions.

Since 2005, there has also been a surge of awareness raising and action within the academic community in the area of climate change research, and in engineering education for sustainable development, resulting in opportunities that I had not originally considered. This includes for example the potential parallel and synergistic process of greening university campus operations, and the potential for considering dual track strategies for postgraduate and undergraduate curriculum renewal to address short and longer term societal expectations. Witnessing this emergence of research I realised the need to iteratively review the literature (evidenced by the numerous 2009 and 2010 publication references in Chapters 1 and 3) and also engage in a number of rounds of peer review (presented in Chapter 5), to ensure that my research was in tune with the emerging field of education for sustainable development.

Considering these shifts in my perspective and position in relation to the research, I conclude that they have acted to strengthen my original values. For example, I still believe that working on the curriculum that engineers experience is a very important point of departure from existing research into timely capacity building for sustainable development to date, and that is also an important contribution to the broader pedagogical question of how curriculum renewal may be accelerated in urgent and challenging times. The research also supports my initial intent to focus on the urgent need for engineering curriculum reform to address 21st Century challenges. I still believe in the notion of rapid curriculum renewal, albeit with a longer lead time than originally anticipated, as there still does not exist the critical mass of catalysts arising from accreditation bodies, professional organisations, potential graduate employers, or government, to drive rapid curriculum renewal in engineering education, in most cases.

In summary, my belief in the possibility of rapid curriculum renewal is a mantra that I will carry forward into further research, but one which has become grounded in the reality of challenges and opportunities that can henceforth be explored by myself and other researchers in this emerging field. Furthermore, in considering the challenges and opportunities, future research might also consider perspectives such as project management and change management.